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TEACHER THINKING AND INTERCONNECTEDNESS: TEACHERS' THINKING ABOUT STUDENTS' EXPERIENCES AND SCIENCE CONCEPTS DURING CLASSROOM TEACHING

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TEACHER THINKING AND INTERCONNECTEDNESS: TEACHERS' THINKING ABOUT STUDENTS' EXPERIENCES AND SCIENCE CONCEPTS DURING CLASSROOM TEACHING

by

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Dissertation

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Doctor of Philosophy

The University of Texas at Austin

August 2004

DEDICATION

This work is dedicated to my parents

Rohini Devi Upadhyay and Kedar Nath Upadhyay

ACKNOWLEDGEMENTS

I acknowledge my wife, Jennifer A. André, for her support, patience, encouragement, and for editing my work. I would also like to thank my brother Shiva Sharma and my sister Nirmala Regmi for encouraging and supporting me to get the best possible education. I would also like to thank the André family and the Upadhyay family for their support.

A special acknowledgement goes to Dr. Angela Calabrese Barton at Teachers College, New York. You have been a source of inspiration and guidance throughout these years. You have set a great example of what a mentor should be and I am very fortunate to have had the opportunity to work with you. Thank you for everything!

This dissertation would not have been complete without the support of the Linking Food and the Environment (LiFE) Program. I would like to thank Dr. Isobel Contento, Dr. Pam Koch and Marcia Dads, at Teachers College, New York, for including me in the LiFE Program.

Thank you to my committee members, Dr. Petrosino, Dr. Barufalid, Dr. Bethel, Dr. Empson, and Dr. Gleeson. Your support and understanding during this process has been highly appreciated. I would also like to thank my fellow graduate students in Science and Mathematics Education. You have made my experience a memorable one.

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Publication No.______________

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The University of Texas at Austin, 2004

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This study examined 4 elementary school teachers' thinking during science teaching in 2 urban schools in the southern United States. Most of the students in these schools come from minority families with low socioeconomic status. The teachers involved in this study were participants in the Linking Food and the Environment (LiFE) program, a curriculum designed for urban elementary students to learn life and environmental sciences. The research employed cross-case study methodology to understand teachers' thinking and the decisions they made during classroom teaching. Fifteen science lessons were taped (7 videotaped and 8 audiotaped) for each teacher over a period of 7 months. Six stimulated recall interviews were conducted to elicit the teachers' thinking and decision-making process during teaching. Data were analyzed using William and Baxter's (1996) discourse analysis framework. Three factors that influence elementary school teachers' thinking and the decisions they made during science teaching emerged from the data analysis:

1. Most teachers believed that students' experiences could be used during teaching, but they disagreed about the usefulness of students' experiences in teaching science for understanding. Two teachers who perceived their students to be less intelligent did not use students' experiences during teaching.

2. All the teachers in the study asserted that students must have the knowledge of science process skills to succeed in science investigation and high-stakes tests. These teachers also believed that mastering science process skills aided in students' understanding of science concepts.

3. In an academically high-performing school, the school administrators played a less significant role in teachers' thinking and decision making than in an academically low-performing school. Administrators were under pressure to "teach to the test" so that students would perform better in the high-stakes test. Teachers perceived a higher incentive for teaching science for better scores in high-stakes tests than for understanding.

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CHAPTER ONE

INTRODUCTION

Background

Teaching and learning has to take place in the context of students' experiences and a good curriculum (Barton, 2001; Delpit, 1988, 1995; Freeman, 1994; Gallagher & Tobin, 1987; Greeno, Collins, & Resnick, 1996; Lave & Wegner, 1993). How teachers perceive the role of student experiences in the science classroom is an important factor, because teachers deliver change in classrooms and thus control the outcome of any educational reform. What teachers do before, during, and after their classes evolves from their experiences and cognitive processes (Clark & Peterson, 1986; Marx & Peterson, 1981; Miguel & Angulo, 1988; Mitchell & Marland, 1989; Yinger & Clark, 1987). In other words, teachers influence classroom outcomes based on their thinking.

Teachers' thinking and information-processing skills guide them toward rational actions to suit situations that they face in their professional environment. During classroom interactions, teachers have to make many important decisions about teaching and learning. Some of these decisions are to satisfy administrative requirements (Calderhead, 1996; Clark & Yinger, 1987; John, 1991; Shavelson & Stern, 1981), and others involve students in learning. Classroom interactions are very difficult to plan, because the nature and scope of the interactions can be understood only after the interactions have taken place. Many teachers associate successful classroom teaching with (a) an uninterrupted flow of activity and (b) timely completion of topics (Fischler, 1994; Tobin & McRobbie 1996). Many science teachers think that science learning happens when teachers can teach science topics in an uninterrupted and no chaotic environment where topic completion is the major goal (Brickhouse & Bodner, 1992; Tobin, Briscoe, & Holman, 1990; Tobin & McRobbie, 1996).

To provide a reform-oriented curriculum of learning science for urban students, in 1998 scholars of Science Education and Nutrition and Health at Teachers College (in press), New York, designed the Linking Food and the Environment (LiFE) curriculum (see appendix C for sample lesson plan). The curriculum focuses on students' learning science concepts through (a) active hands-on activities, (b) critical thinking opportunities, (c) sharing of personal experiences as a part of science learning, and (d) parents as partners in science learning. The LiFE curriculum supports students' science learning in three ways:

1. It allows students to share their outside classroom experiences during discussions and questioning (Boulton & Panizzon, 1998; Brickhouse, 1994, Landson-Billings, 1995; Staver, 1998).

2. The curriculum allows teachers to focus on conceptual teaching and decision making rather than factual knowledge (American Association for the Advancement of Science [AAAS], 1993; National Research Council [NRC],

1996; O’Neill & Polman, 2004). This is achieved through implementing the QuEST learning cycle (see Appendix C). This learning cycle demands that students and teachers have open discussions in the science class.

3. It allows students to do hands-on activities and search for new ways to improvise experiments that can answer questions.

The LiFE curriculum, in theory, allows teachers to understand students’ perception of science content, ability, and knowledge. It provides teachers an opportunity to understand dispositions about students, environment, teaching and learning. Rather than the individual teachers’ preference ways to promote learning, the contexts of academic, school, and classroom influence learning (Eraut, 1994). Many teachers fail to realize that knowledge used in one context does not essentially guarantee the transfer of learning to another context (Munby, Russell, & Martin, 2001). Therefore, these teachers cling to work that is familiar to them and whose outcomes are predictable because they predict a greater likelihood of having a class run smoothly. On the other hand, when teachers try new practices, these uncharted territories present a higher risk of losing control over classroom activities and desired outcomes.

The author utilized participants from the LiFE curriculum in urban elementary schools in the southern United States to conduct a small-scale study to determine if and how teachers support students’ experiences as a part of science learning in their classrooms. All participating teachers explained that they would very much like to have students bring in their questions, experiences, and knowledge while learning science. All the teachers explained, “Students know many things from various sources and they need a place to talk about and clarify their misunderstanding or understanding.” However, one teacher said, “I’m not sure if students know about science.” Nonetheless, teachers were aware that learning science is about understanding concepts and making decisions that allow learners to relate content to their social context.

Therefore, what does it mean to use students’ experiences during teaching? How do these experiences influence science content that is taught? What do teachers think and decide during teaching? By focusing on teachers’ thinking and decision-making process during teaching, this investigation was designed to answer many perplexing questions about teachers’ thinking and decision-making and the role of students’ experiences in that decision-making process.

Rationale

Providing relevant science knowledge that supports students’ real-life situations is one of the goals of a science curriculum. During classroom interactions and planning, teachers’ thinking is influenced by the subject-matter content, classroom context, and school administration (Calderhead, 1996; Clark & Peterson, 1986; John, 1991; Marland, 2003; Peters, 1984). The National

Benchmarks and AAAS reports have advocated that students are the center of science learning. In order for the students to be the part of science learning, their life experiences have to be included in science lessons. At the same time, teachers are the leaders in science classrooms; they must support contextual learning. In that regard, educators, curriculum developers, professional development programs, and teacher education programs can benefit from understanding teachers' thinking during science instruction about students' experiences and science content.

Purpose of the Study

The purpose of this study was to investigate teachers' thinking and decision-making process during science instruction involving student experiences. Closely examining the teaching practices of teachers who participated in the LiFE program can lead to understanding teachers' thinking and decision-making process regarding their perceptions of students' experiences as a part of science teaching and learning. Additionally, this study examined the factors that influence teachers' thinking and their decisions about using students' experiences while teaching science.

Research Questions

Evaluation of science classes of elementary school teachers has raised numerous research questions concerning the teachers' thinking and decision-making process. The following research questions guided this study:

1. What do teachers' think when using students' experiences during interactions with students?

2. How do the experiences students bring to the classroom influence the science content that the teacher teaches?

3. What do the interactions between teachers and students look like when students share or bring their experiences in the classroom?

Significance of the Study

The study showed several significant points.

1. For science education programs, this study addressed a need to educate teachers so that they can implement curricular reforms. Because teachers are the implementers of any educational reform, they must be adequately prepared for success of those reform efforts (Czernaik & Lumpe, 1996; Czernaik, Lumpe, & Haney, 1999; Duschl, 1990, Shulman, 1986).

2. For curriculum implementers and developers, this study outlines the factors that can influence the outcome of curriculum implementation program. Teachers' differentiated epistemological understanding of reform-based

curriculum can lead to unsuccessful results, because teachers may perceive curriculum as the guide to classroom instruction without any regard to student input (Grossman et al., 1998; Hillocks, 1998). Therefore, it is important to identify teachers' thinking during classroom interactions.

3. The investigation of how teachers include students' experiences as a part of science learning and usage is important if science education is perceived as providing useful life tools. Not only is improvement of elementary science education a part of the National Science Education Standards and Benchmarks for Science Literacy, it has been prioritized by the constant improvements in the statewide high-stakes science test requirements (AAAS, 1993; NRC, 1996; Texas Education Agency [TEA], 2003). This study benefits educational researchers as well as elementary school teachers because successful reform is the key to effective science teaching and learning.

Limitations of the Study

This investigation was limited to the small sample population. This limits the generalizability of the study. This study may be also limited to the curriculum implementation program in which the teachers participated. The investigation pertains only to urban schools with a high minority and low socioeconomic student population.

Organization of Dissertation

The first chapter introduced the reader to the background of the study, the purpose of the study, and the description of the LiFE program.

Chapter Two presents an overview of the literature related to teacher thinking. Broadly speaking, the literature review includes (a) teacher planning, (b) teachers' decision-making process, (c) teachers' beliefs and thinking, and (d) teachers' decision making in a given context.

Chapter Three describes the methodology used to investigate teacher thinking. A brief rationale for the cross-case study and the framework for data analysis are presented in this chapter. A detailed description of data collection methods is also included.

Chapter Four presents the findings of this study in thematic sections. Findings from classroom observations, stimulated-recall interviews, and curriculum artifacts are presented in this section. Also a brief life history of each teacher is presented to help the reader understand the context of the study.

Chapter Five includes discussions of each of the themes described in Chapter Four. Finally, the chapter concludes the dissertation with implications of the study and future research possibilities.

CHAPTER TWO

REVIEW OF THE LITERATURE

Overview

Teaching is a complex activity that involves planning, interactive thinking and decision-making processes, teachers' theories and beliefs, and content knowledge. The success of any educational reform relies heavily on classroom teachers' performance (AAAS, 1993; Brophy & Good, 1986; Carter, 1990; Connelly & Clandinin, 1988; Day, 2003; Duschl, 1990; Hillocks, 1998; Putt, 1996). Teachers control the outcome of any educational reform because they deliver the change in the classrooms. Teachers' classroom actions are influenced by the interactions between teachers and students, classroom contexts, nature of the content, and school environment. Teacher's actions are also heavily influenced and determined by a teacher's cognition (Borko, Livingston, & Shavelson, 1990; Broome, 1982; Calderhead, 1993; Clark & Lampert, 1985; Colker, 1982; Duschl, 1990; Elbaz, 1983; Lauriala, 1992; Morine-Dershimer, 1991; Pope, 1993). What teachers do before, during, and after their classes evolves from their cognitive processes. Classroom outcomes are influenced based on teachers' thinking. Teachers have the authority to direct and guide student knowledge, behavior, conceptual understanding, classroom interactions, and various other activities that take place in class (Clark & Yager, 1980; Miguel &

Angulo, 1988; Shavelson & Stern, 1981). Teachers' thinking and information-processing skills guide and orient their actions to suit situations that they face in their professional environments.

Teacher Planning

Teachers' thinking and decision-making processes are most widely studied in the area of teachers' lesson planning. In general, lesson planning involves thinking about activities and anticipating future activities and actions. Planning takes place both internally and externally. The mental process of planning is internal in nature. Observable processes are external in nature (Peters, 1984). The mental part of planning constitutes visualizing the future and developing a guiding framework for future actions. The observable part of planning is to put the plan into action (Clark & Peterson, 1986; Peters, 1984). Teacher planning is a proactive cognitive process that teachers undertake before teaching their classes. The purpose of teacher planning varies from teacher to teacher. Some teachers plan to fulfill administrative requirements, some plan to help substitute teachers to teach their class, and some do both (Calderhead, 1996; Clark & Yinger, 1987; John, 1991; Shavelson & Stern, 1981).

Studies have found that experienced teachers are more successful in adapting their plans to the situation than are their inexperienced counterparts (Berlak & Berlak, 1981; Brickhouse & Bodner, 1990; Broome, 1982; Duschl & Wright, 1989; Grossman, 1990; Lampert & Clark, 1990; Munby et al., 2001;

Resnick, 1989). Most beginning teachers stick to their plan even when the plan needs alterations (Calderhead, 1996; Duschl & Wright, 1989). According to Peters (1984), teachers' planning is influenced by complexity of a task, teachers' intentions about a lesson, goals and objectives of that lesson, and experience gained from each interactive teaching event.

Some interactions are very difficult to plan because the nature and the scope of interactions can be understood only after the interaction takes place. For example, content-specific interactions are hard to plan because student understanding is unknown until after the interactions (Carnahan, 1980). Thus, content-specific interactions influence the planning of the following day's lessons. Additionally, unexpected behavior during teaching makes teacher planning difficult, despite a teacher's experience. Many researchers have found that teachers' plans are (a) seldom successful during teaching and (b) often altered from the original plan. These discrepancies between a plan and its realization arise from situational factors and the "nested" nature of written plans (Clark & Dunn, 1991; Morine-Dershimer, 1991; Peters, 1984; Shavelson & Stern, 1981). An example of a "nested" plan is one that prompts a teacher to answer certain questions only in certain situations. Many beginning teachers lack in-depth knowledge of many factors that influence their classroom actions and thus develop plans that are either incomplete or unworkable (Calderhead, 1996; Duschl & Wright, 1989). Also, in-service teachers' plans are more focused towards addressing management issues. Their plans are designed to please students by answering their questions; this ensures that the class runs smoothly (John, 1991).

Interactive Thinking and Decision-Making Processes

Students are the active audience for both teacher planning processes and implementation processes. However, factors such as teachers' content knowledge, classroom environment, students' sociocultural context, and school environment influence teachers' interactive thinking and decision-making processes. Many researchers (Colker, 1982; Marx & Peterson, 1981; Moje & Wade, 1997; Pope, 1993) reported that most of teachers' thinking during teaching (interactive thoughts) deals with instructional processes such as procedures and strategies. Though planning provides a general and broad outline with possible situations and management issues, prior planning gets sidelined once the teaching commences (Borger & Tilleme, 1993; Clark & Yinger, 1987; Hill, Yinger, & Robins, 1981). Teachers have to make decisions based on their thinking about what students are asking and about the teachers' goals or expected answers. Moreover, in a multicultural environment, teachers need to think about the external experiences and contexts that students bring into the classroom and to make decisions regarding whether or not to use those cultural inputs.

Interactions With Students in Decision-Making

Teachers interact with the students in a variety of ways. A review by Clark and Peterson (1986) summed up that during teaching, teachers' thinking about learners is directed towards being cognizant about learner perceptions, learner interpretations, learner anticipations or expectations, and learner reflections or self-awareness. The connection between teachers' thinking and their actions in classrooms with students is governed by how the teachers interpret the observed cues they receive from the students, such as questioning, taking notes, participating in activities, and conversing with friends (Broome, 1982; Clark & Peterson, 1986; Wittrock, 1987).

Teachers make choices while interacting with students, and those choices are based on conscious decisions. Teachers' decision-making processes are controlled by cues or *trigger points* from students. Trigger points, in most instances, tend to be behavior problems such as side talking or being off task. After observing these trigger points, the teacher either decides to respond immediately or later, depending on the situation. If these cues or trigger points are within a teacher's tolerance limit, he or she will make the decision to continue teaching without any change in the social or cognitive behavior (Clark & Peterson, 1986; Marland, 2003; Wittrock, 1987; Wodlinger, 1980).

Teachers' classroom decisions are based on the performance of students in the class. In most cases teachers face decisions when students have questions, during transitions from one concept to another, and while managing student behavior (Broome, 1982; Marland, 2003). For example, if a student shares an experience that requires a new concept to deliver an answer, the teacher makes a decision either to talk about the new concept or to ignore it. In most cases, teachers' decisions are based on the teachers' judgment of student behavior and are more managerial in nature than based on students' pedagogical strengths (Wodlinger, 1980).

Classroom Environment

Wodlinger (1980), in his case study of a single teacher, found that the teacher's decisions were based on their classroom environment. Teachers' lesson planning is specific to given classroom situations and alters as the classroom environment changes (Clark & Peterson, 1986). In an urban setting, classroom environments are very diverse; therefore, teachers prepare their lessons to support student diversity as well as a better learning environment. Studies in urban education have shown that students' cultural diversity as well as learning diversity influence classroom learning outcomes (Barton, 1998a, 1998b; Brickhouse, 1998; Delpit, 1995; Fusco, 2001; Landson-Billings, 1995; Zahur, Barton, & Upadhyay, 2001). Teachers have to create a classroom environment that allows students to participate in a diverse setting while allowing teachers to incorporate their students' prior knowledge or experiences as a part of their teaching (Atwater, 1996; Kahle, Meece, & Scantlebury, 2000; Marshall, 1992; Oakes, 1990; Oakes, Gamaron, & Page, 1992; O'Neill & Polman, 2004).

Classroom environments range from highly teacher centered to highly student centered (Resnick, 1989). Generally, classroom environments of novice teachers tend to be more teacher centered. As teachers become more experienced, their classroom environments become more student centered both in planning and in execution (Brickhouse & Bodner, 1990; Clark, 2003; Resnick, 1991). Marx and Peterson's (1981) study indicated that teachers' planning matched their classroom behavior. They found that teachers who were in their early days of planning focused heavily on covering the content. The more experience a teacher had, the more planning included an instructional process. Marx and Peterson's study also showed that teachers planned differently depending on the nature and emphasis of the subject they were teaching. These studies have indicated that teachers' planning focuses on broad outlines of processes. These outlines change during teaching because classroom environments are dynamic and unpredictable.

Teacher Cognition in Action

Why do teachers resist changing their plan during action? Human nature resists any deviation from a routine (Day, 1984; Fischler, 1994; Lowyck, 1984). Many everyday actions are part of a routine; they occur spontaneously and do not need extra thinking. Teachers are set in their routines and like to continue those routines as long as they perceive them to be working. However, some key factors influence teachers' numerous decisions to elect or not to elect for change during classroom teaching:

1. Maintaining minimal disruption in the class through minimal alteration in the plan (Shavelson & Stern, 1981),

2. Maintaining a low level of information-processing demand on the teacher to suit the situation (Leinhardt, 1990; Shavelson & Stern, 1981),

3. Maintaining real-time information processing to decrease disruption in the class,

4. Using complex cognitive structures to implement preplanned routines and adjust to new information (Leinhardt, 1990),

5. Having schema about teaching and learning (Mitchell & Marland, 1989; Wineburg, 1991), and

6. Feeling time constraints during digression from their normal plan (Berlak & Berlak, 1981; Lampert, 1985).

A teacher's decision is based on information about how the planned lesson is proceeding (Calderhead, 1996; Clark & Peterson, 1986; Shavelson & Stern, 1981). Most decisions have to do with student behavior; the teacher must choose between (a) continuing the lesson as planned or (b) adjusting or changing the existing plan (Clark & Peterson, 1986; Shavelson & Stern, 1981). As stated earlier in the student section, most teachers are reactive in nature. Teachers tend to change their plan if students’ behavior causes disruption to the class environment and the teachers have suitable solutions to that problem. In the absence of any viable alternatives to influence the classroom environment, teachers do not make any decision to remedy the problem (Clark & Peterson, 1986; Shavelson & Stern, 1981).

During planning, teachers develop a mental script (schema), or image, of how the plans will be implemented. Having such a mental script reduces the information-processing demands on the teacher and allows the teacher to maintain the flow of the lesson (Shavelson & Stern, 1981). At the same time, teachers do not like any disruption in such a schema because it impedes the flow of the lesson and requires extra effort to generate new schema in a short time.

Mitchell and Marland’s (1989) study, based on 6 Australian high school teachers, supported the idea that teachers use mental scripts to help reduce the information-processing demands of teaching. Their study showed that the teachers’ mental scripts about teaching are more general in nature and independent of prior planning. On the contrary, Shavelson and Stern (1981) maintained that teachers’ mental scripts are complex and influenced by prior experiences. Both experienced and inexperienced teachers have similar interactive thoughts, but experienced teachers make fewer interactive decisions compared to inexperienced teachers. Thus, expert teachers seem to be able to reflect well on their activities while engaged in their area of expertise (Brophy & Good, 1986; Kosunen, 1994).

Teacher Beliefs and Theories

Teacher education programs and professional development programs initiate teaching and learning as socially, individually, culturally, and historically framed actions. Nonetheless, teachers tend to teach according to their own theories and beliefs on instruction. Clark and Yinger (1987) posited that teachers' thinking and behavior are guided by a set of beliefs. Similarly, their conceptions of teaching are based on espoused theories that they have acquired or learned. Teachers have implicit theories that influence their actions. Carter (1990) defined these implicit theories as "conceptions of the personal values, beliefs, and principles that seemed to guide action" (p. 300).

One of the most important aspects of research in teacher beliefs, theories, knowledge, knowledge structures, and conceptions is to understand in depth the teachers' personal journey. Therefore, in all research, particularly in social sciences, researchers have struggled to look at their work through the participants' perspective. If the goal is to understand teachers' beliefs, theories, knowledge, knowledge structure, and conceptions, then teaching needs to be examined through the lens of a "teacher's story" (Freeman, 1994). Personal narratives are the means to understand an individual's beliefs, knowledge, and experiences, because individuals understand and relate their experiences through those narratives (Casey, 1993; Clandinin & Connelly, 2000; Drake, Spillane, & Hufferd-Ackles, 2001). Personal life stories provide researchers with a window to make sense of people's personal beliefs, knowledge, and experiences as well-knitted nets of complementary parts.

In the subsequent pages the research literature is summarized in areas related to (a) teachers' general beliefs of teaching and learning, (b) teachers' conceptions of subject matter or content knowledge, and (c) teachers' beliefs about teaching in a specific context.

Teachers' General Beliefs About Teaching and Learning

Teachers tend to act according to their own theories and beliefs on teaching. Day (1984) claimed that teachers have their "espoused theory" and "personal theory." His study of in-service teachers showed that teachers are more likely to change their espoused theory into a "new personal theory" if they can reflect on and discuss their experiences. These theories then can help teachers define classroom tasks and select cognitive tools to interpret, plan, and make decisions regarding such tasks. A teacher's beliefs play a critical role in interpreting behavior and organizing knowledge and information (Pajares, 1992). Carter and Doyle (1995) suggested that teachers' beliefs about teaching and learning function as guiding principles in that they "(1) define what is recognized as notable in the stream of experience; (2) specify how issues and problems can be thought about; and (3) persist even in the face of discrepant information" (p. 188).

Teachers' beliefs about learning are closely connected to their subsequent decisions during teaching. Fischler (1994), in his qualitative study of 2 beginning physics teachers, found that teachers hold "learning as a unique process which comes about almost automatically and which only requires the presentation of the subject" (p. 175). Also, beginning teachers hold a strong view that fundamental requirements to successful teaching are flow of activity without interruption and completion of a topic in the given time. Therefore, teachers who have such views about teaching and learning trust that as soon as the teaching process is complete, the learning process ends as well.

Another study on teachers' beliefs asserted that teachers construct their own ideas about teaching and learning and trust them to the extent that those ideas become nonperishable principles of teaching and learning. Tobin and McRobbie (1996) called such rules cultural myths. Those myths are situated in teachers' teaching and learning schema in the form of (a) transmission myth, (b) efficiency myth, (c) myth of rigor, and (d) myth of preparing for standardized tests. Tobin and McRobbie suggested that these myths are based on two basic sets of beliefs: (a) beliefs about the nature of knowledge and (b) beliefs pertaining to the distribution of power. The authors also noted that these cultural myths support the existing status quo and foster resistance to the enactment of a student-focused curriculum. Fischler's (1994) findings concurred with the efficiency myth and myth of rigor. In his study the teachers believed that completing the task without a hitch completed the teaching as well as the learning processes. He also noticed that "external activity-oriented criteria play a more important role than considerations about learning" (p. 178) during classroom teaching.

Teachers' beliefs of teaching and learning also are strongly linked to their personal teaching practices. Gallagher and Tobin (1987), in a study of 16 Australian high school science teachers, found that the teachers tended to equate task completion with learning. The teachers in their study believed that their job was to cover the content material in the text in the given time. The teachers left the responsibility of learning to students. Gallagher and Tobin pointed out that the majority of class time was spent in whole-class interactions, with teachers having a considerable amount of control over the pace of the lesson. They also found that the teachers, for the most part, interacted with only the top 25% of the students during whole-class interactions. If these "target students" appeared to understand the content, the teachers moved on to a new content area or topic. Teachers' beliefs on teaching and learning have a profound impact on how teachers interact in class; therefore, what happens when teachers' beliefs contradict with their practices?

Czerniak et al., (1999) study of 107 K-12 science teachers revealed that the teachers “believe[d] that including cooperative learning in the classroom can help increase student learning, make science more interesting, increase problem solving ability and help student learn cooperative skills” (p. 128). However, the same teachers also believed that cooperative learning increases off-task behavior and takes up too much class time, leaving less time for other important activities. The study found that the concern for off-task behavior is a stronger predictor of the teacher’s intention to not to use cooperative learning. Therefore, teachers’ belief about the negative influence of cooperative learning on class management influences their decisions on discontinuing a cooperative learning environment. Bandura (1986) agreed with the notion that beliefs are the best indicators of the decisions that people make in their lives. The reality is that people act on what they believe.

Metaphors help to externalize teachers’ beliefs about teaching and their role as a teacher. In one study, Carter and Doyle (1987) identified several metaphors that teachers use to describe their beliefs about teaching and learning. One teacher portrayed her role as a driver navigating a complex and treacherous route. Another teacher characterized her role as a defender of a territory or a commodity. These types of metaphors revealed their potential actions in a classroom. Gurney’s (1995) study of preservice science teachers’ metaphors pointed out the beliefs held by these teachers about teaching and learning. Gurney identified some key beliefs about teaching and learning among preservice teachers: (a) Teaching is an information transfer process, (b) teaching brings change in pupils that produces growth of knowledge, and (c) teaching and learning are personal and humane activities.

How do beliefs about teaching and learning develop? The National Science Education Standards (NRC, 1996) advocated for science learning to be active and inquiry based. This means that students do activities rather than observe something that is done to them. Additionally, today's students are tomorrow's educators. Therefore, their science experiences in schools shape their beliefs about teaching and learning (Calderhead & Robson, 1991). Not surprisingly Calderhead and Robson found that preservice teachers held vivid images of teaching from their experiences as students. Clark (2003) suggested that preservice teachers have to discover their beliefs about teaching and learning at an early stage during their career so that they can reformulate their beliefs.

Teachers' Conception of Subject-Matter (Content) Knowledge

Science has diversified into many divisions within the disciplinary lines of biology, chemistry, and physics. Consequently, most people learn science as a fact-laden course with a very narrow focus. Teachers, when they were students, tended to receive a narrowly focused, divided, textbook-based, and didactic classroom experience. These kinds of experiences resulted in the belief that science, by its nature, is “cut and dried” (Tobin et al., 1990).

Educators, researchers, and policy makers have tried to emphasize the importance of helping teachers to understand the nature of science and the way it should be taught in schools. A large body of research in science education has studied teachers’ conceptions of subject matter, but these studies have emphasized teachers’ conceptions of the nature of science (Abd-El-Khalick, Bell, & Lederman, 1998; Bell, Lederman, & Abd-El-Khalick, 2000; Brickhouse, 1990; Brickhouse & Bodner, 1992; Duschl, 1990; Hodson, 1993; Lederman & Zeidler, 1987). Several studies have established that there does not appear to be a link between teachers’ conception of the nature of science and their teaching behavior (Abd-El-Khalick et al., 1998; Bell et al., 2000; Brickhouse & Bodner, 1992; Hodson, 1993; Lederman & Zeidler, 1987). Bell et al. studied 13 preservice high school teachers and their conceptions of the nature of science. They found that the teachers had views of the nature of science that were consistent with contemporary conceptions. Additionally, the teachers indicated that the nature of science was an important instructional goal for them personally. However, none of the teachers thought that they had addressed sufficiently the nature of science during their teaching. The teachers gave three principal reasons for not incorporating the idea of the nature of science in their teaching: (a) The teachers saw conflict between teaching the nature of science versus teaching the science content and process skills, (b) the teachers needed a substantial amount of time to teach the nature of science and keep up with other teachers, and (c) teachers lacked confidence in their own understanding of the nature of science. These findings concurred with those of Hodson's (1993) study of 12 secondary science teachers. Hodson found that teachers who held clear and consistent views about the nature of science did not plan hands-on or laboratory-based activities regularly. Instead, as is common among teachers, they were more concerned with issues of classroom management and course content coverage.

In another case study of a middle school science teacher, Brickhouse and Bodner (1992) found that teachers can have opposing views of what science is and what it means to teach science. In their case study subject's view, science was an open-ended, inquiry-based subject. Contrary to this belief, the teacher believed that his role was to transmit knowledge to his students in a way that students could make sense of the knowledge. For the teacher, a scientist was a person who seeks new knowledge. At the same time, the teacher viewed students as just wanting to get better grades. Therefore, the teacher's distinction between a scientist and a student was against the basic philosophy of the nature of science (Bell et al., 2000; Lederman & Zeidler, 1987).

None of the aforementioned studies showed that the beliefs about the nature of science influence teachers' classroom practices. However, they provided some evidence that teachers' beliefs about the nature of science may influence their practices. Brickhouse (1990) found that the 3 science teachers' views of the nature of scientific theories, scientific processes, and scientific progress were correlated with their views about teaching and classroom actions. Two teachers considered science "to progress by the accumulation of facts rather than by changes in theory." Similarly, they expected their students to "learn by accumulating bits of information" (p. 57). On the other hand, the third teacher in the study considered science to progress "through new interpretations of old observations and…students learn science not only by assimilating new information, but also by thinking about old information" (p. 57). Brickhouse concluded that these 3 teachers' teaching strategies appeared to be aligned with their views about the nature of science.

Teachers' Beliefs About Teaching in a Specific Context

According to Munby et al. (2001), "Teachers' knowledge is heavily dependent on the unique context of a particular classroom" (p. 877). Shulman (1987) and Grossman (1990) categorized teachers' knowledge of context as one of many categories of knowledge that teachers possess. When teachers encounter students in the classroom, they have to navigate through many complex situations and make choices that have both personal and practical meanings (Lampert, 1985; Munby et al, 2001). Therefore, a preservice teacher has a mental model with hardly any context-specific information. Consequently, these teachers make teaching and learning decisions based on their general conceptions of teaching and learning. With the passage of time, teachers develop context-specific conceptions that help teachers connect their past experiences to current problems, define new problems, and test possible solutions to those problems (Calderhead, 1996). Once teachers have developed relevant knowledge (suited for the task of teaching specific material to specific students in a specific environment), teachers use their acquired knowledge to guide their activities and reduce the mental load of teaching.

Because learning is an active constructive process, students make meaning of what is being taught through a series of dialogues "involving persons-in-action," which allows the students to become members of the learning community, or classroom (Driver, Leach, Millar, & Scott, 1994). Cognitive theories agree with the above notion that learning is a dialogic process and "learning occurs not by recording information but by interpreting it" (Resnick, 1989, p. 2). In their review of *Cognition and Learning*, Greeno et al. (1996) pointed out that in "situative/pragmatist-sociohistoric perspective views, knowledge [is] distributed among people and their environments, including the objects, artifacts, tools, books, and the communities of which they are a part" (pp. 16-17). Therefore, a teacher's perception of students is an important contextual variable. On many occasions teachers fail to recognize students' ability, interest, and classroom environment as well as their own dispositions about students, environment, and teaching and learning. Contrary to the rational view of teaching cognition, studies have shown that teachers' preference of ways to promote learning is influenced by academic, school, and classroom contexts (Eraut, 1994; Lave & Wegner, 1993; McCarty, Wallace, Lynch, & Benally, 1991). Many teachers fail to realize that knowledge used in one context does not essentially guarantee transfer of learning into another context (Munby et al., 2001). This study was conducted in an urban school setting; therefore, it is important to understand the present context of urban science education.

Urban Science Education

Characteristics of urban areas include (a) having a high ethnic minority population with less education, (b) being home to a significant number of immigrant families, and (c) having a high poverty level (Lollock, 2001; U.S. Census Bureau, 1998). Reform efforts have articulated that science education must go beyond acquisition of science knowledge (AAAS, 1990; NRC, 1996). In many urban schools, students do not receive the opportunity to take demanding courses such as science and mathematics. Many students in urban schools are guided by school staff to take lower track courses. Students are expected not to do well in mathematics and science, and many schools do not perceive urban students as high achieving (Oakes, 2000; Oakes et al., 1992). Therefore, urban schools knowingly or unknowingly promote education that stresses basic knowledge acquisition as the goal of school education. Haberman (1991) labeled urban school teaching as “pedagogy of poverty” because teaching in urban schools lacks hands-on activities, critical thinking, problem solving, and discussions. Instead, urban school teaching is oriented towards information delineation, questioning, reviewing assignments, monitoring behavior, grading, and monitoring seat assignments. Haberman also argued that if teachers do not perform these activities, they are perceived as abnormal teachers by peers and administrators. Urban schools also suffer from an accountability load because their students continually have to get better grades on high-stakes tests. Therefore, teachers in urban schools tend to teach factual knowledge in science rather than conceptual understanding (Anyon, 1997; Carlson, 1997), even when reform-based teaching has shown improvement in minority, urban, middle school students’ science achievement and attitudes towards science (Kahle et al., 2000).

Another problem with urban schools is that they tend to blame parents for their students’ behavior problems (Cullingford, 1996). Urban schools are culturally diverse; students bring their home culture into the classroom and learn in ways that are different from the mainstream population. McCarty et al. (1991) pointed out that teachers have to accommodate students who are different from the mainstream students in their teaching practices and in their curriculum design. Without such multicultural understanding and teaching practices, teachers may perceive students from poor minority families as not having the discipline and etiquette to learn in the disciplined culture of school (Barton & Yang, 2000; Davies, 1997; Lee & Fradd, 1998). Fusco (2001) argued that in urban settings, learning science is not just about mastering the content, but also about making learning science a part of a broader community activity. Students have to believe that learning science is a part of understanding their experiences in a rational way. Fusco also argued that interest in learning science has to come from the "concerns, interests, and experiences" of the learners (pp 871). Therefore, teaching and learning science has to be a part of everyday life. Students should believe that learning science helps them to understand their everyday experiences, and teachers should use those experiences as a part of science teaching.

Research Framework

During classroom interactions, teachers' decision-making processes happen within a teacher–student community context. Though this community is different from its members' typical social community, the interactions, exchange of ideas, constraints, roles, and values and beliefs relating to the actions have their roots in the sociocultural environments of the participants.

The theoretical framework for this research and analysis is based on the premise of a mutual relationship between the individual interactions and the sociocultural environment (Vygotsky, 1978, 1987) that they live in or interact. In this regard Rogoff (1995) suggested that the "use of activity or event as the unit of analysis with active and dynamic contributions from individuals, their social partners, and historical traditions" (p. 140) generates a uniquely transformative relationship between the participants and "the social and cultural environment in which each is involved" (p. 140). Therefore, in classroom situations, students and teachers participate in a cultural environment to which each brings his or her individual experiences.

According to Williams and Baxter (1996), teaching that includes students' experiences, values, and prior knowledge as a part of learning helps to produce knowledge. As for teachers, inclusion of students' experiences, prior knowledge, and their beliefs and values shifts teaching and learning from a didactic process to more of a constructivist learning process. In this case, even though the teachers ultimately control the direction of classroom interactions, they recognize the importance of students' input in their teaching and decisions-making processes (Nathan & Knuth, 2003; Rogoff, 1995; Williams & Baxter, 1996). Similarly, Rogoff contended that people participate in various communal activities as a unit, and each one influences another's actions or thinking. As teachers make classroom decisions for a certain action, they simultaneously prepare for the next action based on information from previous ones.

Williams and Baxter (1996) looked at the influence of students' experiences (discourse) in teaching and teachers' decision-making processes based on two levels: (a) analytical scaffolding (conceptual understanding of contents) and (b) social scaffolding (social behavior and expectations). Each of these scaffoldings helps to guide teachers to make appropriate decisions during teaching. During classroom interactions, students' input and the teacher's actions based on those inputs shape the type of sociocultural experiences that are valued during science learning. At the same time, the teacher's validation or acknowledgement of students' experiences creates a climate that is in line with reform-based initiatives. Williams and Baxter acknowledged the tensions that the teachers face while implementing a reform-based curriculum. Balancing students' input based on their sociocultural contexts and science concepts is a real challenge. To this end, the current study's analysis of the data collected during the implementation of the LiFE curriculum increases understanding of teachers' thinking during classroom interactions. The analysis used classroom interactions as units of analysis with a cross-case study as the overarching methodology.

The research reviewed shows clearly that the kind of knowledge that teachers use in everyday work relies on the students, their experiences, the teachers' thinking and experiences, and the school community. In summary, teachers have to be mindful about the contexts of their professional environment. Teachers also must be willing to adopt the view that students are active learners who have pre-existing dispositions about content, leaning, and teaching. Finally, schools should create an environment that promotes active learning.

Most previous studies have focused on understanding teachers' thinking in relation to their actions before or during classroom teaching. Educators, psychologists, teachers, curriculum developers, administrators, and anyone associated with teaching and learning know that teacher thinking affects teacher action, which in turn affects teacher thinking. The review of literature demonstrated that until recently, most teacher-thinking research has investigated the influence of isolated constructs. What is missing in the research on teacher thinking is the connection between teacher thinking and the collective influence of various factors that shape teachers' actions in a classroom. Teachers' thinking is shaped by various social, cultural, historical, and academic factors. Additionally, many mediating or interconnecting variables affect a teacher's thinking and actions, such as school environment, gender, student context, ethnicity, and classroom discourse. Researchers have hardly scrutinized multiple areas of teacher thinking within a single study. To gain a better insight into the complex and dynamic cognitive life of teachers the influence of multiple factors on teacher thinking has to be studied. This study was an attempt in that direction, designed to fill that gap in the literature. However, it was beyond the scope of this study to understand the relationship between teacher thinking in action and the factors that influence teacher thinking. Therefore, this study focused on the connection between teacher thinking and action and students' experiences and science content.

Summary

Critical issues in current teacher thinking research literature were reviewed in this chapter to provide a foundation for this study. The literature review examined existing research on teacher planning, interactive decision making, teacher beliefs, urban science education, and context-specific teaching and learning. The review demonstrated that little research has occurred in understanding the connection between teachers' thinking and students' experiences in a science classroom. Therefore, the current study examined the implementation of the LiFE curriculum in an urban middle school science class to increase understanding of teachers' thinking during classroom interactions. The methodology of the study is presented in Chapter Three.

CHAPTER THREE

METHODOLOGY

Overview

This study used cross-case study methodology utilizing the construct of emergent themes as the determination of data analysis (Boyatzis, 1998). The proposed research questions described earlier were based on possible emergent themes. The open-ended, overarching question of this study was, What are teachers thinking during science instruction about (a) students' experiences and (b) science content? The purposive sampling of this study included teachers who supported students' experiences in the science classes; however, the study was designed to determine teachers' thinking and decisions about students' experiences in science class. As the class observations and stimulated recall interview process with the teachers progressed, several unanticipated themes emerged regarding teachers' thinking and decision making and students' experiences and science content.

Rationale for Cross-Case Study

This qualitative study was conducted utilizing cross-case study methodology. Miles and Huberman (1994) described cross-case study as comparative study. Therefore, this study does not differentiate between the two, and it is beyond the scope of this study to discuss cross-case study and comparative study in detail (see Miles & Huberman, 1984, for details). Cross-case study was chosen because it best suited the need to research and describe a phenomenon that could not be explained through quantitative methods or a qualitative method that would require a priori knowledge. This methodology allows the researcher to compare and contrast the processes and themes across different cases. Complex and sophisticated descriptions and more powerful explanations provide better understanding of the phenomenon under study. Teachers' thinking about students' experiences and science content during science teaching is a complex, everyday event that can be best described through cross-case study. Asking teachers about their decisions and thinking contributes to further understanding of the phenomenon. This understanding allows curriculum developers to design (a) improved teacher education curricula and (b) better science curricula to address the needs of diverse student populations. This also enables teachers to enact effective science instruction.

Meaning of Cross-Case Inquiry

A case can be a phenomenon, a person, or a place where a phenomenon takes place. Therefore a case is a "bound context" (Miles & Huberman, 1994, p. 207-208) where a phenomenon is happening. According to Yin (1984), many cases can also contain sub-cases that are part of a larger case. Yin noted that case studies investigate human actions in their natural or semi natural environment without any interruptions.

On the other hand, cross-case study is a kind of multiple case study. Cross-case study allows accumulation of pertinent information in the social context under study. In this case, meaning is accomplished from the construction of knowledge between researcher and participants. Cross-case study offers researchers deeper understanding of the phenomenon by allowing comparisons among multiple cases under the same theme. Thus, cross-case analysis improves the possibility of generalizability. However, Denzine (1983) and Guba and Lincoln (1981) have not supported the idea of generalizability in qualitative study, because the population sample is small and purposefully selected and qualitative study relies on personal interpretations. Nonetheless, cross-case analysis allows for deeper understanding and explanation of outcomes and themes. According to Glaser and Strauss (1967), multiple cases can inform researchers about the possibility of a certain event occurring in a given situation. Noblit and Hare (1988) added that cross-case study preserves uniqueness and provides comparisons for themes.

Purposive Sample

The purposive sampling for this study was elementary school teachers in two elementary schools in the southern United States. These teachers are participating in the implementation of the LiFE curriculum (see Appendix C for a sample lesson). LiFE is an environment and life science curriculum designed to teach science in a reform based manner that allowed maximum student participation and discussions. The implementation phase of the LiFE curriculum began in 2002 and through collaboration has reached six states. Most of the schools that have participated in the LiFE curriculum serve minority and poor urban populations. The curriculum was designed at Teachers College, Columbia University, New York; The University of Texas at Austin Department of Science Education is one of the partners. Before implementing each new module, the teachers go through detailed workshops so that they can provide the best science instruction possible.

Four teachers from two elementary schools participated in this study. The teachers were matched according to their years of experience teaching elementary science (descriptions of each teacher are provided in Chapter Four). Among the 4 teachers, 2 taught fifth-grade science and 2 taught fourth-grade science. The teachers taught from the LiFE curriculum twice a week; on other days they used the school district–mandated Full Option School Science (FOSS) curriculum. All the names used in this study are pseudonyms to preserve the anonymity of the participating teachers and their respective students.

Data Collection

Data for this study were collected from a variety of methods. The stress was placed on videotaped and audiotaped classroom interactions and stimulated recall interviews. The data collection process also included detailed observation notes. As noted, 4 elementary school teachers from two elementary schools in an urban school district in the southern United States participated in the study. The following data collection methods were used: videotaping, audiotaping, stimulated-recall interview, and other data points.

Videotaping

Each teacher's seven science lessons were videotaped. The videotaping of the lessons was spread over 5 months in the 2003–2004 academic year. Each lesson was about 40 minutes long. During the videotaping, the camera followed the teacher to capture the interactions between the students and the teacher.

Audiotaping

For each teacher, eight science lessons were audiotaped. The audiotapes were placed in four locations within the class to capture all interactions between the students and the teacher. The reason for using audiotapes instead of videotapes was based entirely on the lower cost of the audiotapes.

Stimulated-Recall Interview

Teachers were interviewed six times each after videotaping the lessons.

The stimulated-recall interviews took place at the end of the school day. In some instances, because of other important school commitments, teachers could not volunteer for interview the day the videotapes were recorded. In such cases the interview took place the earliest possible day so that teachers could provide the best response during the stimulated-recall interview sessions. During the interviews the teachers watched their classroom teaching on a digital video and answered questions related to their actions during teaching. Most of the questions during the interview were open ended to elicit detailed responses from participating teachers. All stimulated-recall interviews were based on the videotaped classroom interactions because videotapes provided all the actions that happened during the class, including students' and teachers' nonverbal expressions.

Other Data Points

Other data included school curriculum, LiFE curriculum, and student interactions. These data provided verification of teachers' responses with other information.

Data Analysis

All the data collected were analyzed or coded using NVivo software; coding developed emergent themes. Nvivo allows the researcher to analyze qualitative data by supporting processes of coding in an index system that searches texts or patterns of coding. The units of coding were not limited to a phrase, sentence, or paragraph; the basis of a unit was developed on complete thoughts. The units of coding prevent researchers' taking respondents' thoughts out of context and misconstruing their stories. Twenty-two categories for codes were identified and then developed into five larger themes (see Appendix A). The data were analyzed two different times to determine if any information was initially overlooked. Also, to further insure that the codes and themes were consistent across the cases, a graduate student in Educational Administration volunteered to code two randomly selected cases.

The cases were studied as single cases and then combined with other cases in a matrix to generate common themes and outcomes. Systematic comparisons were performed along the way until solid outcomes were ascertained. Unique outcomes were examined very carefully to strengthen the outcomes. Once the researcher determined that no new codes could be generated by continuing data analysis, the data were compiled into one large data set.

Establishing Trustworthiness

All research has to have trustworthiness in its methodology as well as in its data analysis process. During this study, trustworthiness was established through creating credibility, transferability, dependability, and conformability

(Erlandson, Harris, Skipper, & Allen, 1993; Lincoln & Guba, 1985; Tashakkori & Teddile, 1998). Credibility is the most important component of trustworthiness. In this study, credibility was established through triangulation of data generation and collection, purposive sampling procedures, member checking, and a personal reflexive journal.

The first requirement of credibility was established by engaging with the participants for a prolonged period of time. The researcher was involved with the 4 elementary school teachers through the LiFE project since the Fall of 2002. During this time the researcher, as the project coordinator, observed, organized, and provided feedback to the teachers while implementing the LiFE curriculum. Thus, being a member of an organization "enables the researcher to learn the culture of the organization over an extended time period…and…also helps the researcher build trust and develop rapport with the respondents" (Erlandson et al., 1993, p. 133).

Triangulation was achieved by using multiple sources of data and methods that would emphasize credibility. Triangulation is the process of validating each piece of information with at least one other source (Lincoln & Guba, 1985). For example: The class observation data were matched against interview data and the curriculum. If these data sets gave consistent results, triangulation was achieved. Documentation collected included science curriculums, classroom observations, interviews, student interactions, and description of physical facilities.

A third criterion for credibility is member checking. Member checking was completed by asking the participants for clarification questions, providing a hard copy of their interview transcripts for review, and asking for the participants' approval of the summaries of the classroom observations. Participants had the opportunity to leave the study voluntarily at any time, but none acted on that option.

Another aspect of trustworthiness is transferability. This was established through purposeful sampling and detailed description of context to the reader. Full disclosure of the reflexive journal is also available upon request by the reader to provide deeper understanding of the contextual setting.

Dependability and conformability are the other two important parts of trustworthiness. Because dynamic contexts are impossible to replicate, an inquirer audit may be performed to verify dependability. This report contains excerpts from data, findings, interpretations, and recommendations to allow readers to judge the dependability of the investigation. These excerpts are in the appendix and include samples from the reflexive journal, transcripts and summaries from interviews, and definitions of codes used for theme developments.

Inter-rater Reliability

During the triangulation process, the researcher coded two sets of transcribed interviews that were chosen randomly from a set of four transcribed interviews (one for each teacher). The same interview and the codes with the code descriptors were given to a doctoral student in the Department of Educational Administration at The University of Texas at Austin. The researcher explained all the codes to the doctoral student for clarity. After the researcher and the doctoral student coded the interviews, inter-rater reliability was calculated for the interview data. The inter-rater reliability for the stimulated-recall interview data was 84%.

Inter-rater reliability was calculated for classroom interactions, too, using the same procedure. For classroom interactions, the inter-rater reliability was 95%, much higher than that for the interview data. The discrepancy in the two inter-rater reliabilities can be attributed to the use of videotaped lessons to determine the inter-rater reliability for classroom interactions.

Researcher as Instrument

Because qualitative study entails interactions among human beings and their actions, the human experiences becomes a part of the research process. Also, "to get the relevant matters of human activity, the researcher must be involved in that activity" (Erlandson et al., 1993, p. 15). The researcher is the data collection instrument, so stakeholders share meaning making (Erlandson et al., 1993). At the same time, this method results in possible biases and preferences in the analysis and interpretation of the data. Therefore, the reader should know the researcher’s background in detail.

Educational Experiences

I am from Nepal, a tiny kingdom sandwiched between India and Tibet. I grew up in an extended family where at one point 34 members lived under one roof. I had my literacy education at home with my sisters and brothers. I went for formal schooling in 1972 to the school that served many villages within the walking distance of 2–3 hours. I went to Rastriya Prathamic School (National Primary School) for my first formal education in Grade 2. I walked for 2 hours to my school every day. In 1974 my parents moved to another village in Nepal so I attended Grade 3 there. In 1975 I received a National Scholarship to study in a boarding school in Kathmandu, the capital of Nepal. In 1982 I graduated from the high school in the top 1% of my nationwide graduating class of approximately 63,000 students.

I entered Trichandra College in Kathmandu as a science major in 1985. I studied Physics, Mathematics, and Statistics. After completing my B.S., I went to teach science and mathematics to high school students in the local schools. Because of the political unrest and strikes, I lost about 3 years between 1985 and 1990. Thus, my Master in Science (M.Sc.) degree in Physics was delayed. I graduated from the Physics department with a M.Sc. degree in 1992. Right after graduation, I decided to take education courses and get the teacher certification. In 1997 I received the Fulbright Scholarship to study in the United States. I entered the Teachers College, Columbia University, New York, to get my Ed.M. in Science Education. After graduating in 2000, I came to The University of Texas at Austin for my Ph.D. in Science Education.

Professional Experiences

I started teaching in 1986 as a substitute teacher at Bagmati High School. The school served middle- and low-income families from the neighborhood. The proportion of middle- and low-income families was about half and half. My work required teaching mathematics and science to high school students. I worked in this school until 1989-1990. In 1989-1990 I started working in Kantipur School, a combined middle school and high school, as a physics and mathematics teacher. I taught mathematics to middle school students and physics to high school students. Most of the students in this school were from middle-class families.

From 1992 until 1998 I taught physics and integrated science in Budhanilkantha School, the National School of Nepal, serving Grades 4–12. Almost 25% of the students in this school were from extremely poor families representing all geographic and ethnic reasons of Nepal. These students were on full scholarships funded by the Nepalese government. Some of these students had never seen an electric light bulb, a car, or a TV before coming to this school. The school now has about 850 students representing all geographic, economic, and ethnic groups.

Between 1998 and 2004 I volunteered to teach or help elementary middle schools in New York City as well as in Austin, Texas. This kind of involvement has provided me with valuable knowledge about the workings of the school systems in the United States.

I am currently the project coordinator for the LiFE program at The University of Texas at Austin. My duties include providing workshops to teachers, observing LiFE lessons in the science classes, providing feedback to the teachers, seeking feedback from the teachers on LiFE curriculum implementation, providing parent workshops, writing annual reports, and presenting project findings in various national and international conferences.

Summary

This chapter described the cross case study that the author utilized for this investigation. Also, the chapter described the data collection and analysis methods in detail. An analysis framework was provided to make sense of the data using coding to generate clear emergent themes. Finally, the description of the researcher's background provides readers an opportunity to understand the biases and preferences that may have influenced the analysis and discussions.

CHAPTER FOUR

ANALYSIS AND RESULTS

This cross-case analysis sought to determine teachers' thinking processes during science instruction about students' experiences and science content. Short life histories of the 4 teacher participants are presented to provide the context and background of the teachers. These life histories will help the readers to understand the beliefs and thinking of the teachers regarding science, science education, teaching, and learning.

Life Histories: Understanding the Person

Jane

Jane is a fourth-grade elementary teacher in her late 40s who works in an urban elementary school in the southern United States. Her school is in a poor neighborhood with a large Hispanic population. She has taught in this school for 4 years.

During her own elementary school years, Jane recalled doing very little science except for a couple of demonstrations and collecting shrubs and flowers. In middle school she remembered doing some science activities. She recalled that her science lessons were teacher-led demonstrations, and time was spent in “filling up worksheets and writing notes.” During high school she did not take science because she believes that she was “not good in science to do well.”

Jane’s father had a job in the U.S. Air Force that took them to different parts of the United States as well as abroad. As a kid Jane remembered herself as a person who always “ended up in an unknown nation among people who looked different and spoke different tongues.” Jane graduated from high school while she was in Germany. She remembered her years abroad with fondness:

> I got to see what other people looked like, what they did, and how they talked. It was a great opportunity for me to learn about others. The early exposure that I got to the diversity made me appreciate, admire, understand, and respect what others knew. I really enjoyed being around those who looked different than my family and I. I’m different from many other people who live in [my current town] because of my early experiences.”

Jane reported that her experience made her “a better teacher and definitely a better science teacher, a teacher who is more sympathetic to not-so-normal (both different from mainstream and special needs) students.”

As an undergraduate, Jane studied English, philosophy, and history. She studied science for only two semesters, covering some preliminary physical science, life science, astronomy, and Earth science. Jane reported regretting not studying more science during her undergraduate years: “I wish we had more science instead of just couple of beginners’ level courses. This did not prepare me to teach science.” When she received her teacher certification, she felt that she was “not well prepared to do science with lots of hands-on activities.”

Jane started teaching as a substitute teacher for about 7 years. She taught science, mathematics, and history to elementary school kids. She liked this job but worked part-time to take care of her children at home. She practiced most of her classroom management and teaching skills while substitute teaching.

During these years she also saw her daughter struggle with science. Her daughter graduated from a "poor public school with hardly any good teachers and resources for science learning that prepared competent science students." She saw her daughter struggle in college biology classes where "she couldn't perform experiments well in the lab; couldn't understand what the professors taught despite extra tutoring." Her daughter's "sorry" situation forced her to leave science and major in mathematics. Jane now believes that the have got to learn science in better ways."

Jane started teaching in her current school in 1999. She reported that her students are very diverse ethnically but at the same time bring "many new things in to the classroom." She has found that students [have] "so many different experiences, ideas, views, and knowledge that I should use them in my teaching." She expressed her thinking about students' experiences as a "tool that [can] enhance my own learning as well as other students' learning of science, history, or anything." She has found a vast resource of ideas, experiences, and knowledge in her students: "They are eager to learn and share what they know and I do the same. My thinking about what decisions that I have to make in science classes [is] many times based on what my kids bring in the class." She stressed, "If students from poor families do not get the opportunity to learn and be open to new ideas through sharing their experiences and knowledge, then I don't think the nation can expect scientifically literate, college-bound science students."

Jane is a self-learner. She seeks new ideas, new ways to teach, and strives to know more about effective teaching. She does not feel that she has had enough science background, but she likes to have her class full of dynamic interactions. She is very comfortable with the chaotic and noisy nature of science activities that involve young students. She expressed her belief that science classes are supposed to be full of interactions and questions: "I want my students to think, share, and question each other's answers and findings. I want them to act like scientists. I want them to fail and rediscover what the reasons were for their failed experiments." Jane's desire to allow her students to explore science in an open environment shows her commitment to teaching science as advocated by recent reforms, national benchmarks, and good science teaching practices.

Jane sees the LiFE curriculum in a different light than the FOSS curriculum. The LiFE curriculum is what she was looking for in a curriculum: "I want a science curriculum that allow [s] me to be open and free to bring new concepts and contents. Also LiFE curriculum help[s] to bring students in the process of learning as well as managing the day-to-day curriculum." For her, having students as a "part of" the micro-curriculum is a great achievement in teaching: “I [look] at student input in my curriculum as a vehicle to boost confidence and an excitement to learn science.” Jane believes she cannot do many things with the FOSS curriculum because it has too many “worksheets with jumps in the concepts.” Jane sticks to the FOSS curriculum, but at the end of the 9 weeks, she has to return the FOSS kits to the district to be rotated with other schools. By giving teachers a limited time frame to complete a given section, the school district has limited classroom discussions.

Jane believes that the LiFE curriculum provides students with an opportunity to be like a scientist through the QuEST cycle (see Appendix C for detail). She described this part of the curriculum as a means to help students understand the many aspects of doing science and learn from the “scientific errors” they make in the experiments: “[The] QuEST Cycle allows students to learn that errors in science are an integral part of learning…scientists learn from errors and discover new ways to answer a question that (scientists) are interested in.” Because Jane allows sufficient room for student input, she models a constructivist curriculum.

Jane believes that students should be provided with many science concepts so that they can understand the relationships between them and be able to use them in meaningful ways:

> Many ideas, concepts, and knowledge are shared during my science class. I like to introduce new concepts and elaborate on the ones that I think are

> important for students to know…many science concepts are introduced because they are important for [statewide high-stakes tests], too.

Jane reported a need for new concepts that can enhance students' science understanding without weakening their desire to discover more about science.

Jane is a caring science teacher with a strong conviction to support her students to excel in science. She believes that she is not a master in science content, but she is a very passionate science teacher who provides a nurturing social environment to learn and do science. Jane portrayed herself as a teacher who seeks growth by taking professional development classes in science content as well as pedagogy.

Michael

Michael is a fifth-grade elementary school teacher in an urban city in the southern United States. He is in his mid-40s and has been teaching in this case study school for the last 6 years. Most of his students are from Hispanic families; a few are from White and African American families. All of Michael's students come from low socioeconomic status families where many of the parents work two or three different jobs.

Michael remembered that his elementary and middle school science classes involved memorizing scientific facts and answering lots of knowledge-based questions. He also remembered his science classes as being quite inactive:

“We hardly got to do any stuff. Most of the things were guided by teachers with worksheets; not a lot of interactive discussions.”

In high school, Michael took some basic science classes but no advanced classes. He did not feel strong enough academically to take those classes. He believed although he was an average student, he could take some science, but he “decided not to do hard science.” At the college level he took quite a few science classes. He believed that the science classes in college helped him change his outlook towards science and science learning:

> When I was in my undergraduate program, I took this one science class and [it was] the first time I really ever understood the full scientific process. The professor said to me, “It is not the matter of proving something wrong, it’s the matter of proving something right.” That changed my whole aspect of looking at science.

Michael thinks that science teaching and learning is about understanding nature. He pointed out that students need to understand science as a part of their life because science *is* “around them all the time.” Michael strongly believes that science is an active subject that has an open learning agenda*:* “Science is more open ended than, say, social studies or math, where it’s very, very specific. In science you get little more leeway.”

Michael also emphasized that students need to learn science processes because they are an important part of doing science and also fulfill the school district’s demand: “ [The district’s] big thing is to focus on scientific processes, and the district has decided to focus in, and there are certain things I think you need to cover."

Michael feels that a science curriculum should provide enough room for adding and deleting content. He described the LiFE curriculum as very flexible and adaptable to students' knowledge. He mentioned that the LiFE curriculum allows students to view science from the perspectives of their daily lives. He believes that students are more excited about the things that they feel are tangible and useable:"[A] good thing about [the] LiFE curriculum is that it allows me to be open and test the understanding in many ways." As for the FOSS curriculum, Michael expressed, "It is very much guided with our [teachers'] focus on completing the worksheet and moving on. [A] 9-week block curriculum doesn't help either, because it ties me [so I can't] do more."

Michael said he wants his science classes to be remembered as being very open to discussions with productive social interactions. He also wants his science classes to be supportive of student diversity. Though elementary-level science provides broad scientific perspectives, it does not allow students enough time to reflect on their learning:

> My goal for them in science is to have not only the awareness and understanding but at least a[n appreciation for that process because in elementary school you're still forming children's minds….You're throwing [in] a bunch of broad topics. All we do in elementary, unfortunately, is very limited [in] depth in some things but our objective is to provide [an] overall [nd] general, broad perspective and appreciation for different sciences-not too specific to one topic.

Michael loves teaching science and asking students to think critically. Despite limited time, he goes to great lengths to accommodate students' inquisitiveness and to devise a curriculum that fits his students.

Vera

Vera is a fourth-grade teacher in another urban elementary school in the southern United States. She has been teaching in this school for 4 years. The student population is predominantly Hispanic children whose parents work a couple of jobs to keep up with the daily necessities. Almost all the children in this school come from poor socioeconomic families.

Vera did not have hands-on science instruction during her elementary, middle, and high school years. Her science education was "rote learning with occasional experiments. I wish we had more experiments that we could [have done] on our own." During college, she took the required science courses only because her background left her "not well prepared." However, she was very comfortable with mathematics: "I love[d] doing math since I was a kid. I don't know why I didn't like science even when math and science are so closely related. I believe that my school experience made me not like science." Vera expressed unhappiness that she lost the opportunity to learn science in a positive environment: "I have two sons and I constantly tell them that they need to learn science and be good at it. We talk about science now." She now takes time to help her own children to like science and get the best experience in science during their schooling.

Vera believes that her students should understand science to “have [an] intelligent conversation” when they complete their studies. Her focus and thinking about teaching science, including mathematics, her best subject, is to provide elementary students an appreciation for what they learn: “I believe that elementary teachers have [to] help kids to have [a] broad general knowledge of science or math. We just have to provide an environment for curiosity and teach basic concepts.” She believes that her decisions during science teaching should be about getting the concepts right.

Vera also thinks that an elementary school curriculum has to be more guided, because teachers need to cover too many little things in a given subject, and science is full of little concepts. She claimed that the LiFE curriculum is asking too much from her because she does not feel well versed in science:

> [The] LiFE curriculum is demanding for me. I don’t know much in science and the teacher’s guide in LiFE didn’t have enough information for a teacher like me. The activities are good but there is [a] lot of discussions which I feel unprepared for.

Vera enjoys a more descriptive curriculum where she does not have to prepare a lot to teach. She prefers the FOSS curriculum because it is more guided and focused. She believes that elementary students need more focused science rather than broad and open concepts. She likes to have her curriculum well matched with high-stakes tests because her students need to score a passing grade.

Even though Vera is reluctant to make active decisions in science, she genuinely believes that science has to be taught effectively in elementary schools. She also claimed that she would not hesitate to push her students to attain scientific literacy. She is aware of her role as a teacher even though she struggles to keep up with the science content.

Daisy

Daisy is a female fifth-grade teacher in her 30s. She works in a very poor elementary school in an urban elementary school in the southern United States. She has been working at this school for 6 years. The school is in a predominantly African American neighborhood. With the exception of two Hispanic students and one White student, her entire class is African American.

Daisy's science class experiences in her elementary and middle school were very traditional with usual demonstrations and a lot of "writing and note taking from the board." She reported that she "learned" science concepts through memorization and reading textbooks. During high school, she took life science but struggled to keep up her grades because her parents' jobs required moving to new schools.

Daisy studied biology in college. She was not excellent at it, but she felt that she did well. She struggled in laboratory work initially but managed to get through it: “I could have done better if I had some good high school biology. I’m satisfied with what I achieved.”

Daisy believes in teaching good science to elementary students because science affects their success. She also emphasized up to par in science: “I want to do more hands on and discussion, but my students are very weak in science and math…They can’t digest science concepts well. I’m limited by that.” She also expressed concern that by keeping science lessons open for discussions, she confuses her students more than she helps them. She acknowledged a problem in how she teaches science, but maintained that it is the best way for her students: “Science should be taught with discussions and activities, but I don’t think I can do that here….The best thing is to make sure they can tell the right concept in the [statewide high-stakes test].”

Daisy emphasized that she would love to teach the LiFE curriculum because it provides an environment for students to own their learning. However, she also reported that as a teacher of a low-performing school, she could not afford to “lose time [on] things that [will] not help them to become a high-performing school.” She indicated pressure of the high-stakes test and her responsibility to ensure better performance. The FOSS curriculum is district mandated and is focused to guide her students to learn science for the high-stakes test.

Most of the decisions Daisy makes during her science classes are based on her students' need to perform better and inability to understand broader science concepts. She has an ongoing conflict about what she believes about science teaching and learning and what she has to do. She is frustrated that she cannot do more in her science classes than having students fill in worksheets with the correct answers.

Summary

In conclusion, the life histories of each teacher indicated that their past school science experiences influenced their current thinking about teaching and learning science. Though not all the teachers had science in school and/or college, they expressed willingness to provide a better science experience to their students. They also showed an awareness of making their science lessons hands on.

Themes

The themes that emerged from the data are based on teachers' thinking and their decision-making processes based on interactions with students, students' responses to teachers' questions, and teachers' responses to students' questions during science classroom instruction. The three themes are the following:

1. Incorporating students' prior experiences into science teaching is important.

2. Teachers negotiate between teaching science for understanding versus for high-stakes tests.

3. Science process skills are a necessary tool for science investigation.

4. Social scaffolding affects teacher–student interaction.

5. Creating an environment for science discourse is important.

After a thorough analysis of the stimulated-recall interviews, field notes, classroom observation notes, and the audio and videotapes, five themes emerged. These themes answered the three research questions:

1. What do teachers think when using students' experiences during interactions with students?

2. How do the experiences students bring to the classroom influence the science content that the teacher teaches?

3. What interactions occur between teachers and students when students share or bring their experiences to the classrooms?

Theme 1: Incorporating Students' Prior Experiences Into Science Teaching is Important

Effective science teaching and learning incorporates views, experiences, and the knowledge of students into everyday science teaching and learning. Teachers who are interested in reform-based teaching make students an integral part of their science teaching. Reform-based science instruction advocates teaching in ways that allow students to share their science knowledge, experiences, and thinking in the classroom.

Teachers in this study expressed their desire and intentions to include students' experiences in their lesson plans and also in classroom discussions. Teachers' actions showed that they were keen to encourage students to bring their science experiences, knowledge, ideas, questions, and inquiries into everyday science classes. The following excerpts from stimulated-recall interviews indicated that Jane, Michael, Vera, and Daisy want their students to bring their experiences, knowledge, questions, and ideas about science to science classes.

> Jane: I process their information and try to relate to what I know and what they know and connect them to the context as well as the content. Try to find something that they know and their knowledge which is very limited in many ways partly because of their socioeconomic area and partly because our kids don't cut on TV and watch the Discovery Channel, and partly because many of them come from undocumented immigrants, and partly because they come mostly from minority, Hispanic families.

> Michael: I already have a fairly good idea, given the students, I have had enough time to look at them and interact with them and find out how have they traveled; have they been to the beach or mountains; have they been to Mexico or has my experience only been the apartment, or the farm, et cetera. So that they also can play into my planning. Have we gone to my grandparents and where the travel has taken them; what are some of the things that they have learned. I can't get all the things out of them, but I have a fairly good idea and based on just what we are reading from science text and what we have done previously in science, I get a good idea of how to start my lesson from there.

> Vera: I kind of try to find out if they can give some new information about what they have done, heard, or seen at home or other places. Lot of them travel to their grandparents' place in the South [South America] and learn new things. My kids are low achieving in the benchmark tests, so I can't do a whole lot in having their input in my teaching.

> Daisy: Well, I like to know what my students' know. I know that it is important to share with all the students, but I just can't do that a whole lot because they [students] have a hard time connecting to the experience or their knowledge. I use them only so often. As you have seen it just a few times. I definitely want to have them say in my class.

The interview statements indicated the teachers' desire to incorporate students' experiences, questions, ideas, and knowledge into their science classes. The teachers make it clear that accepting students' experiences in class is helpful to students' science learning. However, Vera and Daisy's perceptions of students' abilities also made a difference in how much of students' experiences, questions, ideas, and knowledge became a part of science teaching and learning.

The following paragraphs individually discuss the 4 teachers' thinking and their decisions to use students' experiences in their science classroom instruction.

Jane. Jane describes that her thinking and decisions try to involve students in ways that allow them to bring their home or earlier experiences into the classroom without penalty. She also believes that in her class students should be able to "think things that are real to them" so that students can understand the usefulness of science in their everyday lives. Science learning should not be isolated to the classroom environment. It should be able to take place beyond school boundaries.

In one of her lessons, Jane talked about how heat travels from one place to another. Students provided answers to the question, "Which material becomes hot first if left out in the sun?" One of the students mentioned that her grandmother covers the bottom of a cooking pan before putting it on the fire. Jane used this idea to explain why rough surfaces absorb more heat than smooth surfaces. She also used this opportunity to elicit students' examples related to heat absorption and reflection:

> S4 (female): The iron and steel got hot quickly…
> S4 (female): Wooden stick also heats less…
> S6 (male): Iron and steel is good for
> S1 (female): we boil things in metal pans and bowls.
> S3 (female): Sometime I've seen my grandma putting clay under pots before cooking.
> S2 (male): Why are the pots rough underneath?
> Jane: So, let's start with [S3's] idea. Why do you think her grandmother rubs clay under the pot before cooking? [7-second pause] What happens to the heat? And cooking?

The science concept introduced in this episode is about the rate of heat transfer by different materials. Students talked about how their grandparents at home use different utensils to cook food. Jane used students' experiences to discuss how heat is absorbed at different rates by different surfaces. Jane explained why covering the bottom of a cooking pot with clay is a good way to cook food with less energy. Jane used students' examples to further the discussions beyond what was planned for the lesson. Jane changed the lesson plan because she thought it necessary to provide scientific answers to everyday experiences (Calderhead, 1996, Duschl & Wright; 1989; Morine-Dershimer, 1991; Shavelson & Stern, 1981). Therefore, most of the students in her class participated when Jane asked them to give examples related to the heat transfer concepts. Some of the examples that the students gave were handles of cooking pots made out of plastic, spatulas made out of wood or plastic, and oven mitts used to pull hot cooking pans from the oven. After this conversation Jane decided to do an experiment to measure the rate of heat flow through different materials, such as iron, steel, wood, and plastic. Jane thought that this experiment would provide a concrete example of how the materials used in everyday life transfer heat differently. Jane would not have done this activity if students had not brought their experiences in the class. Jane described her thinking during this episode as follows:

> If we teach them about rain I want them to make connection to snow or hail, and I want them to have that ability. We teach them as precipitation but we call it rain and we leave it there. They are confused between rain and precipitation. We have to make them naturally think about what-ifs and whys and making connection between many things. I was very interested to elaborate on what they shared about heat in the class. Also, it was a good opportunity for me to explain how heat is absorbed and reflected by surfaces. I was thinking, this is great I can now include them in this discussion and make connection. There’re very few moments that things come so easily.

Michael. Like Jane, Michael was also very eager to use students’ experiences and knowledge in his science lessons. The following excerpt is from Michael’s science class on measurement. The discussion was about using different types of measurements. One of the students mentioned that she had encountered her parents using a different measurement system from the metric:

> Michael: Can you measure milk, and oil, and syrup using cups?
> S1 (female): We do at home. The recipes are in cups and teaspoons.
> S2 (female): Yes. So many cups of flower or milk.
> Michael: Can we use milliliters if we don’t have cups?
> S3 (male): No. Because cup is different from milliliters.

S4 (male): Both measure liquid. My mom uses cups to measure flower, oil.
S5 (male): What about pinch? Like a pinch of salt.
S6 (male): Cup and milliliters is same and use both. Tablespoon is equal to milliliters. 15 milliliters is one tablespoon.
Michael: OK. So, cup and pinch are different ways of measuring, and they are all acceptable, but in science we use the metric system only.

Michael helped students to understand that they could use different measuring systems, all of which could be converted into the metric system. He also pointed out that the metric system is the universal system of measurement and the norm in science. Michael guided his students to show how the scientists do science, while recognizing his students' experiences. During this lesson, Michael was prompted to discuss how measuring systems can look different but do the same job of measuring. He further asked his students to give more examples of ways of measuring things that they had seen or used. A student mentioned how people sometimes describe amounts of ingredients in recipes in "scoops" and "pinches." Michael then decided to use this student's example to talk about unit conversion. During this and similar instances, Michael decided to stray from his usual lesson plan in order to addresses students' experiences (Berlak & Berlak, 1981; Duschl & Wright, 1989; Grossman, 1990; Lampert & Clark, 1990; Munby et al., 2001) and also to help students to learn science and be enthusiastic about it.

Michael believes that students, especially those who come from minority ethnic groups, need opportunities to share their knowledge. This kind of sharing in the classroom not only helps the students to learn, but also makes the classroom environment more social. Michael's idea behind this discussion is driven by his desire to bring students' experiences into the learning process:

> I'm more interested in knowing what others know. When you have kids who hardly have access to many things like cable, newspapers, journals, and educated parents, they don't tend to participate in the class for fear of getting the answer wrong. You know, so in this case I was thinking about how I can make these kids a part of classroom. In measurement you have many kinds of ways. We think feet and yards, others think meters and maybe others have something else. I found out some months ago that there are many countries where people use sticks or hands as measurements. Like pinch can be a measurement. I'm constantly thinking and deciding about these things.

Michael's decision to introduce a new concept with students' experiences was one way to provide legitimacy to what students bring into science classes (Barton & Yang, 2000; Fusco, 2001). Also, student experiences provide new opportunities to teachers to introduce new scientific ideas or explanations. The teacher in this case is very successful in utilizing new information to discuss a new science concept. On many occasions, Michael's decisions about using students' experiences are based on judgment calls because he believes that his experiences in the classrooms have "equipped me to sense the time for new decisions." Michael reported sometimes thinking about a student's input and deciding not to use that input in his science teaching because the input would not help progress the science lesson.

Jane and Michael use students' experiences during teaching because they believe that if students bring their experiences into science lessons, they can understand the science behind those concepts. In many of their science lessons Jane and Michael showed that students' academic ability should not prevent teachers' including students' experiences as a part of their lesson plan and teaching. Jane and Michael believe that students who can bring their experiences into the classroom have the ability to understand the relationship between their experiences and the science behind those experiences. The following frequency tables show the level of students' experiences used during Jane (Table 1) and Michael's (Table 2) science lessons.

Table 1

Frequency Table for Jane's Use of Students' Experiences in Two Lessons

Participant interaction	Frequency (second lesson)	Frequency (ninth lesson)
Students' sharing experiences in whole class	13	14
Teachers' use of students' experiences in teaching	8	9

Table 2

Frequency Table for Michael's Use of Students' Experiences in Two Lessons

Participant interaction	Frequency (second lesson)	Frequency (ninth lesson)
Students sharing experiences in whole class	11	12
Teachers use of students' experiences in teaching	8	7

The frequency Tables 1 and 2 clearly indicate that Jane and Michael often use students' experiences in their science classes. Both of them are constantly thinking about how they can use students' experiences in their science lessons. In 10 out of 15 observed science lessons, Jane and Michael used the QuEST cycle and some of the activities from the LiFE curriculum. They also used the discussion samples from the LiFE curriculum to help students bring their lived experiences into classroom discussions. Jane and Michael made decisions to use those experiences in a constructive way. Jane and Michael also believe that they re getting positive results from the students because of increased student participation in the class, better scores in high-stakes tests, and a positive attitude towards learning science.

Vera. Making students' experiences, ideas, and knowledge a part of the teacher's instruction is an important skill. However, Vera's science class presented very few opportunities for students' experiences to be a part of her instruction. On the rare instances that Vera decided to use students' experiences, she was very successful. The observations of Vera's classes, field notes, and stimulated-recall interviews showed that she does not use students' experiences often in her science lessons because she believes that her students are not able to make connections between shared experiences and the science behind them. She also thinks that her students have not achieved better grades in the high-stakes tests because they do not understand the basic science concepts. She also believes that using students' experiences during science teaching will not help her students to score better grades in the high-stakes tests. In the following episode, her students talked about nutrients and diet. They discussed the role of food scientists and the importance of knowing what food contains. One student brought up the issue of "fat-free" food and "diet." Vera was not quite sure how to deal with that situation. She talked about the role of food scientists and how food labels are created. In this interaction, Vera wanted to use this knowledge to "buy food and make decisions" about healthy food choices. However, she did not talk about fat-free or dietary food.

> S1 (male): You can see on the label. What nutrients food has?
> Vera: Yes. How do they write those labels?
> S2 (male): Food scientists analyze the food and find what food has inside it.
> Vera: Scientists analyze the food for different nutrient values and that's what is written. In this soda can what things do you see?
> S3 (male): Sugar is zero….
> S4 (female): It's Diet Coke.
> S3 (male): Why diet?
> S4 (female): I don't know.
> S1 (male): My aunt is on a diet and she drinks Diet Coke, Diet Pepsi.
> Vera: What kind of nutrient do tortillas, rice, flour have? Now you're food scientists. What does diet mean and why do people go on diets?
> S3 (male): Minerals?
> Vera: No. Let's look at this flour label. Now look at these labels and tell me what kind of nutrients does flour have.

Vera did not use the student's input in her lesson on Food and the Human Body. She was more interested in having her students know the skills necessary to read food labels and identify the nutrient contents in the food. Vera acknowledged that she never expected the diet issue would come into the discussion. However, she reported being happy to know that her students were willing to participate in class:

> This was something that I wasn't prepared for but I was happy. The students initiated the discussion and talked about their real life experiences. In my next planning I can use this as a part of my lesson. My thinking was to complete the class with how to read the label than talk about the diet issues. I decided to let the discussion go because it was important for them to know how to read the label.

Vera showed contradiction between what she believes and thinks about using students' experiences in her classroom and what she actually does. During the regular classroom interactions, she did not include student's experiences as a part of her science teaching. She also did not acknowledge the student's input while teaching Food and Human Body. Vera's interest seemed to be in accomplishing the task at hand rather than using student's experiences in teaching. Later, during the stimulated-recall interview, she explained that she likes to have her students share their knowledge and experiences in the class. Vera's thinking at that time seemed to show that completing the lesson as planned was more important than using students' input in teaching. However, she pointed out that her new lesson would include some amount of time to discuss students' experiences related to the content that she is teaching. Therefore, she may change her lesson plans to accommodate her students' input during teaching. In the 8th, 9th, and 11th observed lessons, Vera used some of her students' experiences during her teaching. The frequency of students' experiences used in Vera's classes increased quite a bit during those lessons compared to earlier lessons. Table 3 below shows the comparison between the number of times Vera used students' experiences in the second and the ninth lessons.

Table 3

Frequency Table for Vera's Use of Students' Experiences in Two Lessons

Participant interaction	Frequency (second lesson)	Frequency (ninth lesson)
Students' sharing experiences in whole class	8	12
Teachers use of students' experiences in teaching	1	7

Vera utilized students' experiences more in her later lessons than in her earlier lessons. During her stimulated-recall interview, she mentioned that her later lessons were much easier to integrate with the LiFE curriculum because many of the lessons in the FOSS curriculum match with the concepts in the LiFE curriculum. Vera's decision to use students' experiences more in the later classes can be attributed to three factors: (a) The LiFE curriculum works as a good resource material to help her think beyond the regular FOSS curriculum, (b) she believes that using students' experiences will help students to remember examples from real-life situations that are related to science, and (c) she believes that using students' experiences will result in improvement in the high-stakes tests.

Vera made her students' experiences a part of teaching science through hard work. Vera's thinking during these lessons reflected her commitment to improving her science teaching skills. She decided to change her teaching after missing an opportunity to expand students' understanding of science concepts by not using her students' experiences as a part of teaching science.

Daisy. In Daisy's classes, students' experiences, ideas, knowledge, and input were hardly a part of classroom discussions. During classroom interactions, students' experiences and knowledge played a part in Daisy's instruction only on a few occasions. The following episode is a typical example of Daisy's science class. A student talked about how salt is made. She brought in her own experience with evaporation: A smaller surface area allows less evaporation, so containers with small necks keep the contents warm longer. Daisy talked about the definition of evaporation had the students write it down rather than discuss the role of surface area and the rate of evaporation.

> Daisy: What is that called? When water disappears from any solution.
> S1 (female): When you keep hot coffee or milk in mug with a small mouth it takes longer to become cold.
> S2 (male): So, large mouth will get cold soon.
> Daisy: I want all of you to write down evaporate. We want to do evaporation. What is evaporation?

Daisy wanted to guide students' discussion towards completing the task she had planned. In this case, the task of completing the lesson regarding evaporation was more important than incorporating her students' experiences in concept building. The students brought up a new concept: rate of evaporation and surface area, which was not the part of the lesson plan for that day. All 15 observed lessons showed that Daisy was not enthusiastic about using students' experiences in teaching. Daisy believes that students need to know the science concepts first. She also believes that students' experiences are not that helpful in developing science concepts. She believes that many of her students do not understand the importance of using their experiences in science learning. Unlike Jane, Michael, and eventually Vera, Daisy was reluctant to use students' experiences in her teaching. Daisy does not believe that her students will gain anything from this process. Daisy explained her thinking about her decision against using students' experiences during a science lesson:

> The knowledge was good, but my thinking was that it will confuse them. I didn't think that knowing about salt and how fast water cools was that important. My decision was based on what they need to know about solution in science. Also, most of the kids are low performing so, it's not that I don't like it, but I want to cover the IPG s [basic skills] as soon as possible. These students need facts, you know, because they have to know that first before they can understand other things. Also most of their experiences are faulty and need changing.

Daisy is focused on ensuring that her students score higher grades on high-stakes tests. She also believes that the accountability system is more about the teachers' performance than the students' performance. Therefore, she reported pressure to have her students memorize science content that is covered by high-stakes tests. Daisy mentioned a lot of administrative pressure to complete the science lessons and negative consequences for not completing the IPG s on time. All these factors restrain her from using students' experiences in her class. The following frequency table (Table 4) shows how often Daisy used students' experiences in two of her observed science lessons.

Table 4

Frequency Table for Daisy's Use of Students' Experiences in Two Lessons

Participant interaction	Frequency (second lesson)	Frequency (ninth lesson)
Students' sharing experiences in whole class	5	9
Teachers use of students' experiences in teaching	1	3

Table 4 shows that Daisy consistently did not use students' experiences in her science lessons. The occasions when she decided to use students' experiences in her science lessons were the times when experiences clearly matched the science concepts that she was teaching. Daisy's priority was to teach to the curriculum that prepares students for the high-stakes tests.

Summary. Teachers who participated in this study can be categorized into two camps. In one camp are Jane and Michael, who believe that incorporating students' experiences in science teaching helps teachers to teach science in an effective way. In the other camp are Vera and Daisy, who believe incorporating students' experiences while teaching hinders science learning.

Jane and Michael also believe that if students are intelligent enough to bring their experiences and knowledge into science discussions, they are intelligent enough to understand the appropriate level of science that explains those experiences and knowledge. Often Jane and Michael make decisions about the science concepts they need to teach in their classes based on what students bring into science class (Fusco, 2001; Oakes, 1985).

Vera does not strongly believe that students' experiences add to science learning, because many students have wrong science concepts. Sometimes Vera uses students' experiences as examples of science concepts, if the experiences match the science concept that she is teaching.

Daisy is a teacher who does not think that students' experiences and knowledge can be made a part of science learning, because those concepts are mostly based on faulty information. Her decisions are mostly governed by the school or district-mandated goals that are driven by high-stakes test results. Daisy thinks that as a teacher her goal is to progress the lesson goals so that she does not have to hurry to "catch up" at the end of the year. Her decisions on the usefulness of students' experiences and knowledge are based on completing the task and finishing the curriculum rather than utilizing student inputs for science learning (Atwater, 1996; Barton, 1998a, 1998b; Rodriguez, 1998).

Theme 2: Teachers Negotiate Between Teaching Science for Understanding Versus for High-Stakes Tests

Many teachers use students' experiences as a part of their regular science class. When students bring their experiences into science classes, teachers have to make conceptual decisions. In this study conceptual decisions are defined as decisions that teachers make during classroom interactions (a) when students bring in new ideas or questions that necessitate explanations or introduction of new science concepts, and (b) when teachers think or believe that they need to introduce new science concepts to explain the science concept under discussion. Both of these situations demand immediate decisions from teachers so that the students clearly understand science concepts. These decisions are also important because during reform-based teaching, students bring many experiences, ideas, questions, and knowledge from beyond the classroom; teachers have to include these experiences in ways that help students understand, participate, and experience science (Barton & Yang, 2000; Oakes, 1985, 1990, 2000). In the case of 2 elementary school teachers, Jane and Michael make their conceptual decisions to provide broad explanations and also to allow students to observe that their questions, ideas, experiences, and knowledge are an integral part of science learning. Vera and Daisy hardly make any conceptual decisions beyond the regular content that they have to teach.

Jane. In Jane's classroom, she wants her students to learn as many concepts or ways to understand science concepts as possible. Whenever she thinks that students should know a science concept that is relevant to her curricular goals, she teaches it to her students. During the third observed science lesson, students were learning to measure and understand systems of measurements. Jane introduced a new concept of estimation in the middle of her lesson. She also introduced the concept of unit and how it is related to the basic repetition of a unit measurement. Jane decided to introduce the new concepts of estimation and unit to the students during her lesson, because according to her this "concept sounds easy, but it's difficult for fourth graders to understand, and I decided to talk about them since one of the students brought it up in the class." A student mentioned that at times he sees people making guesses about (a) how much food to buy for a party, (b) results of an experiment, and (c) budgeting. Jane did not use this students' input right away, but later in the lesson she cited the examples. Jane's class began with the measurement of objects of various lengths using a meter ruler, a foot ruler, and a measuring tape. Jane discussed the role of estimation while doing hands-on activities. Once students understand how to estimate properly, they can predict results of their experiments more accurately. Jane believes that estimation is one of the skills that her students need to succeed in science. Jane explained her decision as follows:

> My decision to put in the guessing or estimation concept was based on my thinking and belief that there are times when they can't use any instrument to measure. Also, in many science experiments scientists guess the results before they start the experiments as their hypothesis. This allows scientists to figure out if the results are OK. I want my students to have that ability and able to guess and predict their results. You know predictions are important because they are hypotheses of sorts. It also helps students to think.

On the other hand, Jane taught conceptualizing measurement in a very unconventional way. She decided that students could improvise measuring instruments that fit their needs. She wanted to give students a way to estimate lengths that help them in situations such as tests and problem solving. This episode depicts how Jane helps students with the concept of improvisation and allows them to believe that being creative is a way to build better concepts. In this case she wanted students to find a way to measure length using their body parts (digits).

> Jane: What do you think about the size of your fingers?
> S5 (female): Using the length of your fingers.
> S3 (male): But they are not equal.
> Jane: That's a good point…
> S2 (female): We can use just one finger (showing the index finger).
> Jane: OK. We can use one finger only. But how do you measure small objects like the weight with finger?
> S3 (male): Divide the finger into parts (showing the digits).
> Jane: Good. So, how long is this diary? Use your digit.
> S2 (female): Is it same as estimation?
> Students: 3 digits.
> Jane: Let's find out the length of a digit.
> (Everybody is measuring the length of the digit using a meter ruler. Some are measuring the length of index finger digit, some third finger, and some the pinky.)
> Jane: OK. Stop everybody. Measure the size of the pinky across?
> S1 (male): One centimeter.
> S2 (female): One centimeter.
> Jane: No. Not the length of the index. Just across. (She shows S3 how to measure the length.)
> S3 (male): One centimeter.
> S4 (male): One centimeter.
> S5 (female): One centimeter.
> Jane: Good. So, the pinky is one centimeter. Even if you don't have an official tool to measure, you have a tool on your body.

Jane gave students a way to figure out or estimate lengths without having to use any instrument. Later in the discussion she pointed out that her students can use the digits to answer questions in the high-stakes tests without having to use the ruler. She also pointed out that they can save time and be fairly “confident” in their answering ability. She believes that this enhances students’ ability to think, improvise, and create things. During the stimulated-recall interview, Jane described her decision to teach her students the method of guessing.

> I decided to introduce this way of measurement because lot of times students forget what they have learned. Using finger as a tool allows them to remember the concept of measuring and estimation without compromising understanding. One other reason was that I want them to get the answer in the [statewide high-stakes test].

Michael. Michael believes that teachers have to decide what to teach and what not to teach. During his planning as well as teaching, Michael decides on the important concepts that students have to learn to progress in science. As a science teacher he constantly decides on the depth as well as the breadth of the concepts in his science classes. Like Jane, he is constantly trying to broaden the science concepts his students understand. During the sixth observed lesson, Michael tried to introduce the concept of optimal environment for plants. Initially he talked about the necessary conditions for survival. Soon, however, he made the decision to allow a slightly different concept to come up during the discussion. He started with the broad concept of the environment as a whole. He later introduced the concept of the environment for a specific animal, the beetle, because one of the students asked him the difference between animals that live in the ground and those that do not. During this discussion, he also brought up two other concepts, breathing and mixture. Though he did not explain these concepts in much detail, he made them a part of the discussion to understand the concept of environment. Michael used his students' experiences while discussing the environment.

Michael's use of students' contribution allows them to make relations between different concepts as a part of the same concept. For instance, Michael was teaching his students that air is a mixture of various gases, and when the body takes in air it only uses oxygen. Students asked Michael why they should not say "air" when talking about breathing. Michael explained to them that animals do not use air while breathing—just the oxygen gas that is present in the air. Michael explained that breathing produces energy when oxygen mixes with food. Later he connected this discussion to explain how beetles survive in the wet soil but not in the dry or soggy soil, which has very little air flow. Michael believes that connecting different concepts to understand one science concept such as environment improves students' critical thinking and problem-solving skills (Michaels, 1981). Michael's decisions during science lessons are based on two factors: (a) The experiments in science do not always give the results that are expected, therefore students sometimes must rethink their hypothesis or explanations; and (b) science involves a connection among many concepts, and teachers need to address these connections in class to provide full conceptual understanding.

> I decided to not just let them say "air." I wanted them to understand that animals need oxygen. That was the decision I made as I was discussing with them about the beetle's environment. I constantly change my

> thinking and the lesson plan because I sometimes feel that more specific concepts have to be introduced to better develop their science concept.

Jane and Michael's lessons develop and progress with a lot of student input. Both of these teachers use students' experiences as a part of their curriculum. These 2 teachers allow their curriculum to be inclusive of students' input and therefore more constructivist in nature (Hillocks, 1998; Kosunen, 1994). During stimulated-recall interviews, Jane and Michael mentioned that their lesson plans change quite a bit because students are continuously allowed to be a part of science teaching. Therefore, Jane and Michael's curriculum is a constructivist curriculum.

Vera. Vera's science classes are distinctly different from Jane and Michael's classes. In Vera's classes, the conceptual decisions are made as soon as the students show a slight confusion in their understanding of science concepts. She introduces no new concepts while teaching her planned content. Out of 15 observed lessons, Vera used students' experiences to teach new science concepts in only 2 lessons. Her 12th observed lesson was on photosynthesis and why plants need light to grow. Her lesson plan related light to photosynthesis. During this lesson, students brought in their experiences about how bean sprouts and covered plants become yellow in the dark. Some students asked about the need to keep indoor plants next to a window. One of the students mentioned that she saw leaves facing towards the window in indoor plants.

S6 (female): If we grow the plants in the dark it will grow more.

> S4 (male): I think so. The bean sprouts grow in the dark.
> Vera: The plant in the dark grows but does it grow better than in light?
> S2 (male): Yes. Plants in the house grow well in dark.
> Vera: Why do we put plants in the light then?
> S1 (female): Leaves of plants inside the house are [facing] windows.
> Vera: It needs light to grow. It needs light. Water and light help it to make food and it is called photosynthesis. There is one more thing that the plant needs to make food.
> Students: Water, light, air.
> Vera: What exactly in air?
> (8-second pause)
> Students: Oxygen, carbon dioxide, hydrogen…
> Vera: Which one of these three? (5-second pause) The plant uses carbon dioxide, sunlight, and minerals to make food, and the process of making food is called photosynthesis. Also in this process sugar is produced as food and oxygen is a waste.

Vera wanted her students to learn that plants need light to grow well and flower. She started her class by discussing the concept of plant growth in a dark environment versus a lighted environment. To fully explain this concept, she decided also to teach photosynthesis. She taught photosynthesis as soon as it appeared as one of the concepts that needed to be addressed from the curriculum. In this short discussion, she made two conceptual decisions, which came together when students showed some confusion in understanding the concept.

> I'm always thinking about what I have to conceptually cover in the class. Lot of times when I find the students going off the track, I want them to understand the original concept first and then move on. When they said air I immediately thought, well, I needed to talk about photosynthesis. I make these new conceptual decisions because it can create confusion or misunderstanding later and do badly in the test….I'm not sure how many times I make conceptual decisions. Generally very few or hardly any in a given class. Sometimes more. It depends on the science concept that I am teaching.

Vera's rationale for making immediate decisions about new concepts or ideas during teaching is definitely based on students' understanding ability and clarity of the overall science concept that she is teaching. Vera is more concerned about having her students get the content correct than talking about their experiences and making those experiences a part of teaching new concepts. She expressed skepticism about the usefulness of students' experiences in the content that she teaches. The most important factor in her conceptual decisions is passing the benchmark and high-stakes test. Vera's thinking is that she must prepare her students to do well in the high-stakes test.

Daisy. When making conceptual decisions in science classes, Daisy and Vera are much alike. Daisy is also more concerned about her students' science abilities. She is also aware that her students have to score better in the high-stakes test. She rarely makes multiple conceptual decisions while teaching a particular science concept. In her fifth observed lesson, Daisy asked students, "What is the optimal environment for beetles to grow?" The students conducted an experiment about where a beetle lives. Daisy kept the students focused on the task without introducing any new concepts. In all of her 15 lessons she hardly allowed students to talk about their experiences. Daisy was more concerned about completing the content that she planned than promoting new concepts. During the lessons, Daisy did not let her students deviate from the task at hand, and she ensured that they write down everything that she put on the board.

> Daisy: Today we will talk about environment. I want you to write down "what is environment." (Students start to write in their notebooks. 13-second pause) So, what is environment?
> Students: Where we live.
> Daisy: OK. So, where we live. What are the things that make an environment? You have to write that.
> S3: House, food.
> Daisy: OK. We will find that out. Here are some beetles, and we will make environment for them to live. We want to know which one is better. We will make three environments for the beetle and see where it lives. (Students are given the materials to create dry, wet, and soggy environments for the beetle and observe where the beetle ends up staying after about one half hour.)

Daisy directed the class to remember the concept at hand and hardly let the class deviate from that task. Daisy's decisions are based on her thinking that students need correct answers to understand science concepts. She also believes that her students need to know the answers so that they can do well on high-stakes tests.

> My thinking is that I have to let them know the real scientific concepts, facts, and ideas as soon as they come up because, you know, these students have to get good score [on the high-stakes test]. Also, my decisions are based on the students that I teach and that if I don't tell them the right thing right away they tend to mix everything and get more confused. More discussions can easily confuse the kids. I want them to have stepwise clear concept.

Daisy's decisions reflect her thinking about teaching science concepts on two levels. First she believes that as a teacher she has to make sure that the right concepts are introduced from the beginning of the lesson. Any delay in introducing the right concepts can foster an even greater misconception by allowing students to recreate a new understanding while still keeping the old misconceptions. Second, she wants to make sure that students understand the scientific concept that she is teaching. In the environment lesson described earlier, she wanted the students to understand that the environment has to support the growth of living things and also sustain the population. The reasons for her decisions in that lesson revolved around her belief that (a) her students possess a low ability to understand science concepts, and (b) her students need to perform well on high-stakes tests.

Comparisons. In most instances Vera and Daisy's curriculum hardly include any student input. Vera and Daisy do not believe that student input is warranted in the curriculum because they believe that including students' experiences deviates science lessons from the goals that they have set. However, this lack of student input in the curriculum is contrary to the philosophy of the reform-based curriculum (AAAS, 1990; Hillocks, 1998; NRC, 1996). The following frequency table, Table 5, shows how often Jane, Michael, Vera, and Daisy used students' experiences during science lessons. The table is a summary of three videotaped lessons (Lessons 8, 9, and 10) made during the data collection process.

Table 5

Frequency of Teachers' Conceptual Decisions Made Based on Instances of Students' Sharing Experiences

Teachers	Conceptual decisions made	Experiences shared
Jane	8	12
Michael	7	11
Vera	2	6
Daisy	1	6

Table 5 shows that Jane and Michael used and elicited more student experiences while teaching science concepts. Jane and Michael had a greater number of instances when students shared their experiences because students' voices were heard and utilized to teach science (Artiles, 1996; Bandura, 1986; Corno, 1989; Delpit, 1995; Ladson-Billings, 1995). Many students in Jane and Michael's classes also mentioned to the researcher that they like to share their ideas, experiences, and knowledge in class because it makes them feel included. In most lessons Jane and Michael were observed talking about students' experiences and using them as examples of different science concepts. Jane and Michael also mentioned in the interview that the LiFE curriculum reinforces their philosophy and beliefs about using students' experiences in science teaching and learning. By using examples from the LiFE curriculum, teachers can watch their students' progress as they develop critical thinking and problem-solving skills.

Table 5 shows fewer instances of students' sharing their experiences in Vera and Daisy's classes compared to Jane and Michael's classes. Students in these two classes bring in their experiences, but those experiences are rarely used during teaching. Vera and Daisy use students' experiences very rarely because they perceive their students to have a low ability of understanding science concepts (Vera and Daisy define the low ability of their students in terms of their performance on high-stakes tests). Another reason for not using students' experiences is that Vera and Daisy are constantly watched. During a period of just 7 months, the school administrators paid about 15 visits to their science lessons. The school administrators check to see that the teachers are completing the district-mandated curriculum and preparing students for high-stakes tests.

Teachers involved in this study use varied levels of students' experiences to make conceptual decisions while teaching science. This study shows that the decisions to use students' experiences depend on the following three factors: (a) the ability of the students, (b) high-stakes testing, and (c) teacher beliefs and thinking.

1. The ability of the students: Teachers who have higher ability students tend to make more conceptual decisions during teaching. The classes of these teachers have more student participation and questions. Often the teachers take the initiative to introduce new concepts relevant to the concept that the teachers planned.

On the other hand, teachers who have lower ability students do not introduce new concepts during their science teaching unless it is absolutely necessary. These teachers believe that using students' experiences can lead to misunderstanding of science concepts under discussion. These teachers tend to make fewer conceptual decisions than those who have higher ability students.

2. Testing: One of the factors that keep teachers from introducing new concepts is the fear of digressing from the science concepts that help students answer test questions correctly. These teachers are more concerned about keeping one scientific concept on track so that students can grasp and be able to use it during the high-stakes test (Borko et al., 1990; Brophy & Good, 1986). Nonetheless, even the teachers of high-performing students are aware that they must teach to the test (McNeil, 2000).

3. Teachers' beliefs and thinking: Teachers constantly think about what they are doing in class and the decisions they should make to let the class flow. Their decisions encompass their beliefs of what they should teach and what they should not and their beliefs about science learning, testing, and their own role as a teacher. Teachers who believe that it is essential to make numerous conceptual decisions to broaden students' science understanding are also the ones that believe in introducing new science concepts within a lesson despite test anxiety.

Theme 3: Science Process Skills are a Necessary Tool for Science Investigation

Another area of a teacher's decision-making process relates to teaching science process skills. For all 4 elementary school teachers who participated in this study, science process skills included observations, measurements, questioning, hypothesizing, and writing conclusions. Jane, Michael, Vera and Daisy all expressed that students need to understand, master, and be able to apply science process skills in the right situation in the correct way. They also expressed that their plan and decisions in science class must focus on helping students understand science process skills and their importance while learning science through hands-on activities.

Jane. During her fifth observed lesson, Jane decided to use the QuEST cycle before starting the hands-on activity. During this lesson she also introduced science process skills in detail to her students. She asked the students to repeat the science process skills verbally and then write them in their notebooks. Jane also told her students that they have to understand science process skills before they can do the activities and understand the results that they get from the activities. Jane began with the skills of question formation as a major part of doing and learning science. She then pushed students to think about the different aspects of science process skills. Jane described her thinking and decisions about teaching science process skills as follows:

> They need to know that in science you start at the question and from there you go around and your question is answered. But along the way what would happen if you change certain things in your questions? Science process skills are the key to getting good results in an experiment. They have to know science process skills for [the high-stakes test] because there are many questions on that.

During the stimulated-recall interview Jane mentioned what her students need to know about doing science. Jane believes that science process skills are necessary if her students want to do science investigation. She knows that students have to know the skills to measure accurately, to observe correctly, to calculate results correctly, and to write conclusions methodically in order to achieve better grades in high-stakes tests. Jane mentioned during the interview that a large portion of the science curriculum for the fourth grade is about science process skills, and that students have to know them "by heart" to score better grades in the tests. She is aware that science process skills are important to understanding science and passing the high-stakes tests. She also emphasizes that science "can be understood better with more understanding of science process skills."

During three different occasions Jane used the QuEST cycle from the LiFE curriculum to do science activities. Her ambition was to go beyond science process skills. She used the QuEST cycle while teaching arm movement. Jane asked students to make the most reliable and energy efficient joint that a human being could have. The activity started with questions and a hypothesis. Students worked in groups of three. The group that the researcher observed talked about how human hands work and soon began to talk about other animal limbs. Students constructed four questions: (a) What kind of joint will be strongest? (b) What kind of joint can lift the most weight? (c) What kind of joint can last the longest? And

(d) What kind of joint will get tired the fastest? The group assembled all the materials and made limbs with different kinds of joints, such as fully rotating or partially rotating. They used the final limb that they made to test for weight and durability. This group's limb did not work as hypothesized. The teacher asked them several questions related to the failure of the limb. The group then started asking new questions and started the activity again. During this whole process, Jane helped her students with guiding questions. Jane did not mention science process skills to the students at all during this activity, which is contrary to her earlier assertion about explicitly teaching science process skills. In her stimulated-recall interview, Jane recounted this activity as being totally different from what she had initially thought of and planned. She decided to change her plan because she thinks that just knowing science process skills is not enough to do "better" science. To Jane "better" science is about doing science activities like scientists do and understanding science as a tool to understand life experiences and use them in real-life situations.

Michael. Similarly, Michael also stressed the importance of science process skills in his classes. Michael's decisions were based on his thinking that students in the fifth grade should master science process skills. His major goal in this regard was to get the process skills right. The conversation began with this question: What is the best environment for brine shrimp to survive? Students provided various solutions to the question. Students' answers contained necessary things such as water and food but not the specifics about how these things influence brine shrimp to survive. Michael stressed that science experiments have a control group that determines the causality and gives a reliable answer. At the same time, Michael also emphasized that his students can learn science process skills such as observing, measuring, and making conclusions during the brine shrimp experiment.

> Michael: So, we have to find out what is the best environment for brine shrimp. How do we do that?
> S3 (male): Dirt, muddy water.
> S6 (female): Stream water…
> Michael: So, where does a brine shrimp live? First you must know that.
> S2 (female): In water.
> Michael: What are we doing? An experiment. So, we need a good science method to really find out where brine shrimp can live well. It's like, can we live in any environment? Obviously not. So, what do we do in an experiment?
> Students: Get a control group.
> Michael: Good. So what is the control environment if brine shrimp live in salt water?

Michael's goals in doing science experiments are to get the process skills right. He believes that once students get the process skills right, they can continue to do so despite the nature of the experiment. Michael's classes showed that he is very particular about his students' mastering the process skills. He wants all his students to clearly understand that without a good understanding of science process skills, they cannot understand the results of an experiment. During a stimulated-recall interview, Michael explained his decisions regarding teaching science process skills and his thinking behind putting so much emphasis on mastering the processes:

> In this case, when I was doing the brine shrimp class, you know, I wanted them to remember that there is a process in science you need to do. Science experiments are very methodical, and I want them to understand that. Also, in science, I want them to see that you need a control group to find out the cause. Also I think about how to clarify that science processes have to be replicable, and new questions have to be answered.

Michael clarified his thinking about following science procedures by stating that science experiments are replicable despite slight differences in the procedures. His belief is that procedures to answer science questions need not be exactly the same among groups who try to answer the question. However, the key is that in science, according to Michael, if questions can be answered using various procedures, then there is legitimacy in variation and the results are more believable. His decisions during this episode were geared towards carrying out an experiment with a “correct scientific method.” Michael’s thinking and decisions on teaching science process skills is also based on the demands posed by high-stakes tests.

Vera. Vera was interested in having her students repeat the experiment and describe how they did it. The emphasis was on using the right science process skills, as described in the IPGs (goals of the district for each lesson), with marginal student input. The students were required to write their procedures on paper, then discuss them. During Vera’s 13th observed lesson, she introduced an investigation to find out if plants store any energy. Vera asked students to identify the science process skills needed to do the activity. Students tried to answer the question with what they knew about doing an experiment. Students mentioned things like hypothesis building and measuring, followed by some other questions. Vera did not use students' input. She told them what science process skills they needed to know to get the experiment "right":

> Vera: Where do we get energy from?
> S1 (female): Food.
> Vera: How do we know that food has energy?
> S2 (female): Because we need energy. We eat food for energy.
> Vera: But how do we find out food has energy?
> S2 (female): We experiment.
> Vera: What do we do in the experiment?
> S4 (male): Take measurement.
> S3 (male): Write hypothesis.
> Vera: Yes. But we have to write it in order. We can't write all over, like measuring first and then writing hypothesis. We get question first and then hypothesis and do the experiment and measure, observe and write conclusion the last.

Vera decided to teach science process skills using more teacher input than student discussions. Though students offered some input on what they needed to do to answer the question on energy, Vera gave them each correct step for the activity. Giving correct procedural steps is a way to ensure that her students know the science process skills involved in the activity. Knowing science processes skills is important for achieving better cores in high-stakes tests. Vera wants her students to pass the high-stakes test because a large portion of the test is based on science process skills. In an environment where teachers' performance is measured by students' score on high-stakes tests, teachers spend more time teaching the contents that have the greatest weight on those tests.

Daisy. In Daisy's science classes, instructions regarding science process skills were very direct. Students hardly provided any input. Most classes were full of demonstrations with few hands-on activities. Most of the time, students were either told or shown how to do the experiment with stepwise instruction, thus reducing student errors in procedures, measurements, or observations. During a lesson on solutions, Daisy asked the students to do a hands-on activity as described in the hand-out. The students followed the worksheet and filled in the blanks as they completed the activity. At the end, Daisy told all the students that they should have 50 ml as the answer. This activity involved little discussion or student input. Everybody followed the procedure as described by Daisy and as written in the hand-out.

> Daisy: We will do an experiment to find out how much salt is in the water solution.
> S4 (female): It's dissolved. Can't find that.
> Daisy: We have to find out how we can measure the salt dissolved. What we will do is first measure (weigh) 50ml of water in the cup. Then measure (weigh) salt solution made out of 50ml of water separately. We can find that out first. I want you to measure the water and solution separately and find the difference between them. You will do that. First write the question which is on the board and write your own hypothesis in your groups. Then do the experiment.

During the stimulated-recall interview, Daisy described some legitimate reasons for not letting students struggle with the experiment. First, a district mandate requires that they finish the lesson on time (by the end of the 9-week block). She wanted her students to be able to do all the activities in the FOSS kit. Therefore, she had to choose between letting the students discover the right process skills and giving them all the process skills to complete the experiment. Daisy chose the latter and provided instructions on how to do the experiment correctly. Her decision to teach the way she does was based on what she calls “jumping the hoop.” In Daisy’s case, the pressure to improve students’ test scores is paramount, because that is how she and the students will be judged. She understands that students need more interaction in science class, but does not believe it to be a realistic possibility.

Comparisons. All 4 teachers put great emphasis on teaching science process skills to their students. They strongly believe that if students master science process skills, they can investigate any science question successfully. The following frequency table, Table 6, shows how often teachers in this study made decisions to talk about science process skills. Decisions in this case were counted as an occurrence when the teacher listed out loud, during the lesson, the process skills to students. During stimulated-recall interviews, teachers verified that the occurrences actually were decisions to talk about science process skills.

Table 6

Frequency of Teachers' Decisions to Teach Science Process Skills During the 5th and the 14th Lessons

Teachers	Occurrence of decisions to teach science process skills
Jane	12
Michael	10
Vera	15
Daisy	15

The teachers made conscious decisions to insure that students understood the importance of knowing science process skills and being able to describe them and use them in their activities. Teachers in this study frequently asked students to write down the names of the science process skills and their definitions. The teachers believe that if students write definitions, they will remember science process skills better during high-stakes tests. At the same time, the teachers' priority is to make students remember the "correct" scientific method and to apply it in science experiments (Tobin & McRobbie, 1996). None of the teachers talked about the scientific method but talked a lot about writing science process skills as a stepwise process for doing science. Nonetheless, all 4 teachers expressed that knowing and learning science process skills is important if students want to pass the standardized tests. All teachers reported their belief that science process skills help in science investigation.

Theme 4: Social Scaffolding Affects Teacher–Student Interaction

Social scaffolding includes interactions in science classes between students and teachers, where (a) teachers ask students to elaborate their ideas, (b) students support each other in activities, and (c) teachers show or mention contributions of students in helping to understand science content (Nathan & Knuth, 2003; Williams & Baxter, 1996). Social interactions between students and teachers are important for they establish a caring and cooperative classroom environment. Social interactions play a major role in classes where students have greater input in their learning. In classes where students' knowledge and experiences are valued and used actively in discussions, social norms and standards determine how well the students will learn.

Jane. Social scaffolding varied in each teacher's classroom in this study. Jane and Michael's classrooms offered an effective environment for social scaffolding. Students and teachers in these classes effortlessly exchanged information, ideas, and questions. In the following episode, Jane tried to introduce to the students the concept that when they want to know something in science, they need to find a question that interests them. This can be done through research, literature reading, and discussion with other colleagues who are doing similar work. The episode showed the nature of social scaffolding between what teachers want students to think and say and what students perceive or think is the "right" answer to the question.

> Jane: What do you have to do when you want to learn something?
> S1 (male): Pay attention.
> Jane: Pay attention, OK. If somebody is talking or giving you instructions you want to pay attention. But if you want to learn something; what [are] some things you want to do?
> S2 (female): Talk and look at the person straight in the eye.
> Jane: Look straight in the eye.
> S2 (female): Research.
> Jane: Where do you want to go for research?
> S3 (male): Internet…
> S4 (male): Encyclopedia…
> S5 (female): Books…
> S6 (male): Ask an expert…
> Jane: Ask an expert. Anybody else?
> S7 (male): Look in the computer.
> Jane: Take notes. Type it in the computer. Anybody else?
> S8 (female): Does it matter who is talking?
> Jane: Who is talking.
> S9 (female): Draw everything and listen.
> Jane: Draw everything and listen. What do you want to do more when you research? Let's go back to [a student's] question. What makes you research? What makes you get started? (8-second pause) If I say potato does it make you go and research?

During this discussion, Jane knew that the students misunderstood her question. The students thought Jane was reprimanding them. However, she never gave them the answer she was seeking. Instead, she looked for responses from them and directed her questions with students' own responses. During this period in the classroom, all the students believed that they had done badly in the previous week's high-stakes test, and therefore their teacher was not giving them the answer. Students also believed that they had to respond to Jane's questions with good behavioral answers like pay attention, take notes, and do homework on time. Students tried to use their prior experiences when interacting with Jane because they knew what worked and what did not. Nonetheless, in other classes, students were not too concerned about giving what they thought to be the right answer.

Jane used students' responses and their experiences to talk about doing science investigations. Jane tried to utilize the QuEST cycle from the LiFE curriculum to help students critically think about science investigations. She struggled to get to the desired goal during this interaction, but she still used students' responses and experiences to achieve the goal of helping students to build critical thinking and problem-solving skills. During the stimulated-recall interview, Jane mentioned that her decision to keep on pushing until her students got it right was based on her thinking that if she decides to give the answer, they will never develop critical thinking and problem-solving skills. She also stressed that as a teacher she thinks about bringing in all the students' experiences and answers to guide them to understand complex science concepts. This also allows her to build a working social environment.

To her students, all of Jane's classes feel like a place where they can support each other and learn science. Jane acknowledges all kinds of answers and encourages students to bring their experiences into the class. Jane's thinking about allowing students to share their experiences is not only based on teaching science for contextual relevancy (Barton & Yang, 2000; Borger, & Tilleme, 1993; Zahur et al., 2001), but also on encouraging student interactions.

In her third observed lesson, Jane asked students to think about what it means to measure and observe during science activities. Leticia, one of the students in the class, asked if observing is measuring. Jane put this question back to the students and allowed them to explain and support their answers.

> Jane: Observing is not measuring?
> Leticia: No. Because when you observe we don't use ruler or any measuring thing.
> Jane: What about when you just look at things and guess how big or small it is?
> Leticia: That is measuring?
> Jane: What do you think? Explain it to me.
> Leticia: Well, measure is like you have numbers and observing is just looking.
> [After 10 minutes of discussion Jane brought in the example of owl pellet activity that her class had done a week earlier.]
> Jane: Remember the owl pellet experiment?
> Students: Yes.
> Jane: How did we find out the animals that the owls eat?
> Leticia: We matched the bones with the picture in worksheet.
> Jane: Did you measure the bones or observe?
> Leticia: Observe and match.

During this discussion, some students talked about how when they observe the sky at night they do not use ruler to measure but use their sight. Some other students remarked that observation is about knowing color, texture, and shape, not about measuring. Jane at this point, as she recalled in her interview, was thinking about using a previous science activity to illustrate how observing is a type of measurement. Jane decided to talk about the owl pellet activity because during that activity they observed various sizes of bones and matched them with those that were on the worksheet. After Jane talked about the owl pellet activity, students discussed how they estimated bone size and matched the bones with the animals listed on the worksheet. Jane used students' experiences to explain how observation is a type of measurement.

Michael. Like Jane, Michael's classes offered dynamic student and teacher interactions. Students participated openly, and the teacher helped to facilitate that openness to promote productive social interactions. The following episode is an example of social scaffolding in Michael's science class. The discussion occurred during a lesson on how salty the water should be for brine shrimp to survive.

> Michael: Today we will investigate the saltiness of water that is good for brine shrimp to grow.
> S3 (male): Salt water is good for brine shrimp?
> S12 (female): Because, like, we don't drink salt water. Too much salt is bad.
> Michael: It is bad, but what might be the reason.
> S12 (female): You have, you can't eat lot of food if it's salty.
> Michael: Why can't we do that? What happens if we do eat salty food?
> S7 (male): We don't feel good.
> S8 (male): We need a cup of salt water, a cup of clear water [unsalted], a cup of muddy water and put the brine shrimp in and see what happens.
> Michael: But how do we know how much salt is good?

Michael wanted his students to brainstorm on how to find out the degree of saltiness that brine shrimp can tolerate. During the brainstorming activity, students not only talked about their experiences with salty food and how people cope with that situation, but also discussed the likely effect of salt on growth. Students offered many different ideas about how to find the optimal salt environment for brine shrimp to grow. Michael encouraged students to be part of the discussion. By doing so, Michael provided an opportunity for his students to express their understanding. Students and teacher participated with a lot of questions and answers to understand why a large amount of salt is not good for humans to consume and how to investigate the strength of salt water in which brine shrimp can grow well.

In the subsequent interview, Michael explained his decision and thinking during this episode. Michael guided his interactions with students by asking himself: "How long will I go and ask the question?" He mentioned during the interview that he gives some "hang time" to his students, but when he senses that nobody will answer his question, he guides them to get the answer or think more about the possible solutions. Michael is always thinking about how he can use students' input in discussions and activities. He also wants explanations from his students so that he knows their level of understanding. Michael expects his students to come to his class with the desire to know more about science. He is willing to accommodate students' curiosities to help them learn science. He believes that as a teacher he needs to promote students' eagerness to learn science.

Social scaffolding is based on mutual respect. Michael makes sure that students do not laugh at others' ideas because that may prevent them from participating in future class discussions. Michael believes that classrooms are social environments. For better learning, social norms and behaviors have to be set to promote learning.

> If we're able to do that we can have a classroom society that is better informed with [a] better foundation and also we could deliver better to the kids.…I at times struggle in trying to come to terms or accommodate these kids so that they have the opportunity to do something that they lacked. I have to make sure that I can connect to the kids and try to find those fine things that would make those connections, and many times I can't find it.

Vera. Vera's classes had fewer episodes of social scaffolding when compared to Jane and Michael's classes. The student–teacher interactions in Vera's classes were mostly based on short explanations for understanding and did not last long during her science classes. The nature of the social scaffolding was mostly about asking students to repeat the answer with little explanation:

> Vera: So, why is air a mixture?
> S9 (male): There are many things in the air.
> Vera: Can you give me example?
> S9 (male): Oxygen, hydrogen, carbon dioxide.
> Vera: So, a mixture is when two or more than two things together.
> Students: Yes.

In this interaction, Vera asked students science knowledge questions and students answered them or she told them the answer. There was very little interaction beyond question and answer. Students hardly brought their experiences into the classroom discussion. Vera decided to keep the interactions short because "it allow[s] students to get the answer." In Vera's thinking, social scaffolding should be limited to asking students questions and allowing students to explain what they have understood during a science lesson. Because this fourth-grade class had more students who are "weaker" (lower achievement in high-stakes tests) than did other fourth-grade classes, Vera believed that she needed to keep the discussions short. During science teaching her goal is "to provide some opportunity to students to clarify their understanding and participate in discussions." Too much discussion can lead to "confusion and misunderstanding. Time [is] the essence and dictate[s] the length of interactions."

Daisy. In Daisy's science class, social scaffolding was almost nonexistent. She likes to have her class focused on knowing the content and remembering them for high-stakes tests. Daisy's students repeated the definitions that she wrote on the board. In her class, students rarely have a longer interaction with the teacher. Most interactions are limited to students answering Daisy's questions or personal conversations unrelated to the science lesson. During a stimulated-recall interview, Daisy mentioned that she did not ask her students to elaborate on why more salt could be dissolved in hot water because she was thinking that this knowledge would not help her students to do better on high-stakes tests. Daisy reasoned that her decision not to have a discussion on solubility was also based on the school district's demand to complete the IPGs before district officials came to her school to check for progress, because her school is labeled as "low performing."

> Discussions are good. I know that I should allow more discussions, but I don't have that much time in my class. Almost 60% of the students failed last year and most of the kids here have limited science concept. I don't think they can handle long discussions because they completely get lost.

> ….I make decisions not to drag the discussion because they are not quite built to handle that.

Daisy is concerned that her students will fail high-stakes tests and she cannot let that happen. She thinks that if students of “lower ability” (according to their achievement in the high-stakes tests) get direct information from the teacher, they are more likely to understand and retain science concepts. She believes that students need guidance when making transitions from memorization to critical thinking.

Theme 5: Creating an Environment for Science Discourse is Important

This section elucidates the nature of science discourse, the role of student input (their experiences, questions, ideas, and knowledge), and the use of student input in science teaching. Teachers not only make conceptual decisions to help students better understand science concepts, they are also instructional leaders guiding students through the science learning process. The learning environment that teachers help create is manifested in the kind of discussions in class (Brophy & Good, 1986; Carnahan, 1980; Claderhead 1993). In this regard, teachers are the leaders, because without their permission and support, students cannot and will not participate productively in class. This section looks at the nature of science classes when students bring in or share their experiences. This section also looks at the role that teachers play in promoting science discourse in the class.

After closely analyzing the data from classroom observations, stimulated-recall interviews, classroom videotapes and audiotapes, and informal conversations with the teachers, the analysis showed that Jane and Michael allowed student discourse to be a part of science classrooms more than Vera and Daisy. Jane and Michael are very eager for students to bring their personal experiences, questions, ideas, and knowledge into their science classes and thus help build an environment for that purpose.

Jane. Jane is cognizant that science learning needs an environment where students can bring in what they know and try it out. Jane wants her students to experiment and discuss their experiences, ideas, questions, and knowledge in her classes. Because she also wants to be a part of that experience, she brings in her own experiences, ideas, and knowledge to share with her students. Jane allows her students to be involved in sharing their experiences and knowledge as a part of science teaching and the learning process. Jane has an open policy about what students can share and discuss, but at the same time provides leadership in the discussion to produce a productive outcome and experience. In the excerpt below, she introduced the relationship between vision and light and allowed student discourse to be a part of her teaching. Jane was introducing a new topic on light and vision and wanted her students to think about this relationship and share their ideas, experiences, and knowledge. The students talked about how night-goggles help them to see things at night and how they can see stars in the dark. Jane allowed this discourse to take place because it brought forth students' misconceptions about vision and light. The following interaction shows how students shared their experiences in the classroom:

> Jane: Can you see in the dark?
> S13 (male): We need light to see some things and not that is powered by light.
> Jane: My question is do we need light to see. We are not talking about energy here yet.
> S2 (female): No.
> Jane: She thinks it's not true. Let's hear from her.
> S2 (female): If you wear night goggles you can see in the dark. I can walk in the dark. When there is no light I can get to the door at home.
> S18 (male): Switch off light (Jane switches off the light). I can walk to the door.
> S8 (female): We know the door. Can't do in new place.
> S16 (female): If the light bounces off the mirror and comes to the dark we can see then.
> S2 (female): Yes. You can see the star in the dark. Lot of stars in the dark and you can see.

After the interaction, Jane introduces the concept that vision and light are related, and without light animals cannot see. They also discussed animals that can see at night and how their vision is different from ours. Students described their experiences of how cats can see at night easily because their eyes are more sensitive to less light than many diurnal animals. During this interaction Jane provided guidance when the discussion strayed from the intended goal of the question or the class. Jane encouraged students to lead the discussion with questions and comments. During the stimulated-recall interview, Jane recalled the above interaction as deciding to provide a space for students' ideas and their knowledge so that they could test them for learning. She stated that her decision at that moment was to give students an opportunity to make mistakes and learn from them. Learning through sharing prior knowledge in a communal environment allows students to reshape their understanding of a given concept (Fusco, 2001; Lave & Wegner, 1993; Resnick, 1991).

The following interaction between Leticia and Jane is an example of social and behavioral expectations and the norms that Jane has for her students. The exchange between Leticia and Jane is also about teachers' desire to facilitate students' ideas, understanding of science concepts, and knowledge.

> Jane: Is observing measuring?
> Leticia: No. When you observe you don't use ruler or anything.
> Jane: What about when you just look at things and guess how big or small it is?
> Leticia: That is measuring?
> Jane: What do you think? Explain to me.
> Leticia: Well, measuring is like you have numbers. Like 2 centimeter and observing is just looking.
> Jane: Give me example.
> Leticia: When we observe the seeds before we put in soil (3-second pause), we write *color, size, smooth, rough*. We don't write *2 centimeter*.
> José: Why?
> Leticia: We don't have numbers.
> José: But observing is a kind of measuring because we can guess numbers correctly.

In this particular instance the rest of the class listened to the discussion between Leticia and Jane with very little interruption. However, Jane allowed José to ask for further clarification or otherwise provide input in the discussion. The discussion continued until Jane finally provided the answer to her question.

Jane's ultimate decision for answering the question was based on her thinking that students need some kind of answer to avoid confusion.

> It is O K to take a chance and even if you got it wrong but without thinking it you are carrying it forward. I sometimes give answers because either I believe that it is necessary or it will be tough for students to find the answer. It might be beyond their ability. Sometimes I just think that it avoids confusion. Can you prove it, can you show somebody something that you did or thought about. Can we have debate or dialogue and talk about what you did, what are your findings, your theory and can you convince others with your findings. My idea is that these kids think and learn science in a manner in which it helps them seek more knowledge.

Michael. Michael likes his students to make the most out of their knowledge and questions and learn science at the same time. In the following discussion on environment, students brought in the question of why certain plants grow in certain climates. Though this was not part of the actual content Michael planned, he allowed students to discuss the relationship between climate and planting. Many students in his class come from migrant families who have lived on farms. These students brought in their experiences, which differed from most other students who grew up in urban environments. Michael provided support for these students to share their experiences with the rest of the class.

> S3 (female): You have to plant like beans in the warm climate.
> S2 (female): Yeah. That's when we harvest it.
> Michael: Why do you have to plant them during warm weather?
> S3 (female): That's when it grows well.
> S7 (male): We plant beans when it starts to get hotter. Not too hot.
> Michael: What conditions do the seeds need to sprout?
> S10 (male): Water, soil.
> S18 (female): Why just water? Can we just make the soil really soggy and plant?
> S3 (female): Yes it will sprout.

S6 (female): Like the bean sprouts. It's in the water only.
S12 (male): At home, you know, the beans and, um (3-second pause), sprouts things soaked in water for some days.

The students freely brought in their experiences, ideas, questions, and knowledge to share with the class, resulting in lively student participation. Michael tried to guide them towards the science concept that he was teaching while allowing students actively participate in the discussion. Michael explained that his thinking behind such decisions is to help students bring their lived experiences into science class and try to find the answers to those experiences. His decision was also based on his belief that unless he allows students to make sense of their experiences, they will not learn the connection between science and their lived experiences. In science, the openness of the questions and discussions allow students and teachers to bring in their discourses as a part of a learning exercise. This helps students learn to question, argue, and appreciate each others' contributions for learning.

In Michael's stimulated-recall interview, he explained his motive for promoting student interaction and critical thinking. He believes that in science students have to be able to apply their imagination and critical thinking skills to understand science concepts. He also tries to create a comfortable environment for the students, both higher and lower skilled, so they feel comfortable enough to share and discuss their ideas with others. The teacher in this case leads the students to build a more complex and better science concept rather than being authoritative.

Vera. Vera and Daisy allow their students to share few of their experiences and knowledge in science class. Their shared goal is to make sure that the science concept goals are covered in the given lesson. Vera and Daisy reported other reasons to keep the classroom environment fairly restrictive. Vera wanted to avoid the risky business of getting tied to "something [that] I don't know." Daisy, on the other hand, was more concerned about completing the science content with little or no input from students because they are mostly at a lower performance level. Both teachers explained their decisions to make the environment fairly restrictive:

> Vera: For me, many science topics and concepts, especially the ones that include physical science, are not easy to explain. We don't have materials to do the experiments, like to show the colors of light, and also I have very little knowledge on the topic. Students have lots of questions, and I feel not comfortable not answering them. Also, if I open the discussion too wide, then I feel that I can get tied in something I don't know. I decide to curb student input if discussion becomes too fragmented. Looking at what I know and what I can do, I restrict the discussion to a limit. However, I know that I have to work on making the environment more receptive to students' knowledge, ideas, and experiences.
>
> Daisy: The reform in science teaching and learning asks us to be open to discussion, students' input, students' knowledge and ideas, but the reality is not that. I want them to learn more, but I can't keep my class too open for discussion because these kids are very low performing and got to get the basics right away. Most of them can't follow if the talk goes everywhere, so I decide to restrict the openness of discussion. Looking at the ability that they have, well, I have to be direct in instruction. Again I hate to say that they have to pass [the high-stakes] test. I think about

opening the discussion for what they know, but I decide against it because, as you know, I have to make the topics simple for them to understand.

Vera reported being willing to provide a constructive environment for students when she is well-versed in the science concepts she is teaching. She is aware that her students need a nurturing environment to share freely their knowledge and questions to better understand science concepts. Observations of her classes showed that she was somewhat receptive to students' ideas but not sure if students could make sense of what they shared in the class. In most of the classes, Vera hesitated to have students share their experiences because she was not sure how to deal with that situation. She was particularly restrictive in her decision to allow students to bring in their experiences as a part of science learning. Vera thinks that there are many questions in science that she cannot answer. Therefore, she is not that receptive of students' discourses. The following discussion on the colors of light shows how she managed students' discourses:

Vera: So, light has seven colors. We can find that out.
S6(female): No. We don't see it's all white or orange.
Vera: O K. We're doing an experiment with prism. I'll demonstrate (shows light spectrum on a white background).
Vera: Do you see them?
Students: Like the rainbow.
S3 (male): There're only four. Red, green, orange, blue.
Vera: O K. Listen to me. There're seven (pointing to each one): red, orange, yellow, green, blue, violet, indigo.
S9 (female): Why do we see red through this red plastic?
Vera: We just need to know that there're seven colors.

During this interaction, Vera was very prescriptive and direct in her response to students' comments. Two students brought in new discourses: one about the rainbow and the other about color. Vera never addressed this input or tried to answer student questions directly. She told students what she thought was important for them to learn. She decided not to explain why a rainbow has seven colors because she did not want to waste time and not complete the lesson. She also acted on her belief that students in her class could not understand complex answers. She perceived her students to be academically weaker because they scored below average in their high-stakes tests (Fusco, 2001). Below-average performance puts pressure on Vera not to deviate from the planned lesson because such performance may be perceived by the administrators as wasting time and not teaching for the high-stakes tests.

Daisy. Daisy reported being caught between her roles as a facilitator and information provider. She knows that her students must understand the science concepts to pass the test; however, they also need to be able to learn new scientific concepts. Nonetheless, she did not seem willing to give up her role as classroom leader. Because her students are less able and thus more likely to fail high-stakes tests, she did not provide an open environment to let the students discuss and bring their knowledge and ideas into the classroom.

Comparison: Teachers who allow students' experiences to be a part of science classroom interactions have a very dynamic classroom environment. Most students in these classes participate as equal partners in learning. Students who are different from the mainstream culture need a class that allows their discourses to be a part of the learning process. Teachers in these classes, such as Jane and Michael, are aware that teacher support is critical to developing a discourse-oriented science classroom.

The following frequency table, Table 7, indicates how often teachers in this study brought in their experiences and allowed students to bring in their experiences during science lessons. The greater the number of times teachers brought in their own experiences, the more likely students were to bring their experiences into science classes. The frequency table shows that on average students brought in their own experiences twice as often as the teachers did. However, further analysis is needed to verify this result, because this finding might be influenced by the LiFE curriculum, which provides support for discourse-oriented classrooms.

Table 7

Frequency of Teachers' Discourse Versus Students' Discourse During the 7th and the 11th Lessons

Teachers	Teachers' sharing discourse	Students' sharing discourse
Jane	8	15
Michael	7	13
Vera	4	6
Daisy	4	6

Teachers who allow discourse in science learning have a very strong belief that science learning happens with active interaction (Tobin et al., 1990, Tobin & McRobbie, 1996). For these teachers, passive interactions mean not making students responsible for their learning. Teachers who do not want lessons to digress from their plan believe that students do not have a part in influencing a curriculum (Hillocks, 1998; Shavelson & Stern, 1981). Thus, the learning in these teachers' classes is less active and more passive in nature.

Summary

Knowing life histories provides some explanations behind teachers' thinking and the decisions that they make during teaching. Most elementary school teachers in this study have very little science background, and most of their thinking during teaching rested on their experiences as a school or college student.

Teachers in this study were divided regarding the idea that students' experiences have to be a part of science teaching and learning. The reasons for using students' experiences as a part of science teaching and learning varied among the teachers, as did the amount of time each teacher permitted the experiences to be introduced in class discussions. Reasons for not using experiences included (a) students' being lower skilled academically, and (b) administrative pressure to complete the course to improve student grades in high-stakes tests.

Teachers also agreed that teaching students science process skills is an integral part of doing science. Some teachers make conceptual decisions based on students' shared experiences. Mastering the "correct" application of science process skills allows students to get the "right" answer during hands-on activities. Teachers in the study emphasized that students have to master the application of science process skills to pass the high-stakes test.

Teachers make conceptual decisions all the time. Teachers in this study agreed that the decision-making process is difficult. They must choose between teaching science for conceptual understanding and teaching for success on high-stakes tests. Furthermore, teachers from low-performing schools in this study reported that they cannot afford to have discourse-oriented classes because those classes tend to disrupt the flow of the class and can cause misunderstanding.

CHAPTER FIVE

DISCUSSIONS, IMPLICATIONS, AND RECOMMENDATIONS

Overview

This chapter discusses the findings regarding the three research questions addressed in this study:

1. What do teachers think when using students' experiences during interactions with students?

2. How do the experiences students bring to the classroom influence the science content that the teacher teaches?

3. What do the interactions between teachers and students look like when students share or bring their experiences in the classrooms?

This chapter also includes the implications of this study and suggestions for future research.

Discussion

Research Question 1

Research Question 1 asked, What do teachers think when using students' experiences during interactions with students?

A teacher's willingness to incorporate students' experiences into science class is a stepping stone for generating an inclusive environment where all students can learn science. Students have to appreciate, understand, and participate in the everyday dialogue around them. Teachers who allow students to bring their lived experiences into the science classroom help in the implementation and application of a reformed science curriculum and also in students' science learning (Delpit, 1995; Marshall, 1992; Zahur et al., 2001).

The 4 teachers in this cross-case study—Jane, Michael, Vera, and Daisy—all reported their belief that science classroom discussions must have room for students to talk and share about their science-related experiences. However, they disagreed on the extent of inclusiveness. Jane and Michael are more open to broad discussions within the science content that they are teaching. Jane and Michael support students' discussions to build an environment that value others' experiences. In their science classrooms, students are quite free to discuss any experiences, both those that support the science content under discussion as well as some that do not. Jane and Michael believe that what they teach has to be a part of what students think or perceive as being useful outside the classroom. The decisions that Jane and Michael make while teaching are based on (a) what experiences are important in advancing accurate science concepts without alienating students from science and (b) what science content should be taught so that students see the connection between science and their everyday life experiences. However, both Jane and Michael acknowledged the following pitfalls in allowing too many students' experiences into a science lesson:

1. Students may think that science concepts have to fit every experience that they have encountered; in other words, science can explain social and cultural habits even though many of these habits cannot be explained using science concepts.

2. To students, science may represent the sharing of experiences rather than using science concepts to explain those experiences or making science a part of understanding those experiences in a more logical manner.

3. Students may have the misconception that all the experiences shared in science class can be explained by the science concept being discussed.

4. Teachers may have to sort out all shared experiences and provide concise and appropriate scientific concepts related to those experiences and still maintain students on task.

5. Teachers may allow a disproportionate amount of participation for some students.

In the cases of Vera and Daisy, students' experiences do not take the central role in their science teaching. This is particularly true in Daisy's science classes. Because her lesson plans do not include allowances for students' experiences, student input comes as a surprise. Daisy's science class is structured more like a traditional science class with task completion as the major goal. Daisy named two major reasons for not being too enthusiastic about allowing students' experiences to be a part of her science teaching and learning. First, she believes that her students have low academic ability, thus they are not able to understand simultaneous scientific concepts. She believes they lack the ability to make the connection between a myriad of shared experiences and the science concepts being taught. Second, she is under a lot of pressure from the district, school administrators, and parents to prepare students for the statewide high-stakes test. Because her school is labeled as "low performing," she needs to make sure that her students do not fail and adversely influence the label that school receives from the district. In addition, she must complete the 9-week block curriculum on time for the students to be able to do hands-on activities. Therefore, the perceived science ability of the students (Marland, 2003; Broome, 1984), administrative pressure, fear of bad labeling, and the block nature of the curriculum influences Daisy's thinking and decisions on whether to allow students' experiences as a part of her science teaching.

In the case of Jane and Michael, their school is labeled as "high performing"; however, they face administrative pressure (Calderhead, 1996; Clark & Yinger, 1987; John, 1991; Shavelson & Stern, 1981) to do constantly better. Nonetheless, Jane and Michael reported less direct pressure from the principal to be on task. Also, Jane and Michael believe that science learning is a cooperative, communal process where students and teachers work together. The LiFE curriculum supports their beliefs about the value of students' experiences in learning science or any other subject. McCarty et al. (1991) and Michaels's (1981) studies suggested that using students' lived experiences can help students' critical thinking and problem-solving skills because students can examine their understanding against the concepts that they are learning. At the same time McCarty et al., in their study of Navajo children's learning style, discovered that teachers can advance higher order problem-solving skills by pushing students beyond their background knowledge or lived experiences. Additionally, students of all abilities can learn and make sense of scientific concepts and the usefulness of those concepts in relation to their experiences with some help from teachers. In these classes, students are more participatory when their views, knowledge, and ideas are valued.

Research Question 2

Research Question 2 asked, How do the experiences students bring to the classroom influence the science content that the teacher teaches?

Teachers use students' experiences to teach science content and concepts at different levels and frequencies. Teachers' decisions to use or not to use students' experiences to teach science concepts depends on the classroom environment (Clark & Yager, 1980; Miguel & Angulo, 1988), students' academic ability, teachers' perception (Peters, 1984) of students' ability, and high-stakes tests. One of the participants of this study, Jane, expresses the need for rapid conceptual decisions during her science teaching:

> As teachers we have to take the leadership role. When our teachings are student centered and where their personal knowledge from home and playgrounds are a part of science learning, teachers have to decide which concepts to teach now and at once and which ones to leave for later. I believe that thinking about conceptual decisions and acting on them is a part of being a responsive teacher. The examples in the LiFE curriculum help me to deal with this.

This study argues that there are two kinds of teachers when it comes to making conceptual decisions. Some teachers make conceptual decisions to explain the questions generated by students' sharing of their experiences, knowledge, or ideas. The other kind of teacher does not introduce new concepts despite having opportunities to do so. The first type of teacher likes to elaborate, introduce, and use new and previously taught science concepts to help students understand and make sense of their knowledge and experiences. This researcher calls these teachers "inclusive decision-makers" because they introduce new concepts as much as possible and urge students to use these science concepts to answer their experiences. Jane and Michael are highly inclusive decision-making teachers. Another characteristic of inclusive decision-making teachers is that they connect the required curriculum content with new content that comes out of student–teacher discussions (Hillocks, 1998). The second type of teacher is more concerned with completing the concept covered by the curriculum. This researcher calls these teachers “non-inclusive decision-makers” because they do not make students’ experiences a part of their conceptual decisions.

This study has shown that the conceptual decisions in science classes are based on three factors: (a) teachers’ perception of students’ academically ability, (b) high-stakes testing, and (c) teachers’ beliefs and thinking.

Teachers’ perception of student’s academic ability: In this study, teachers with higher ability students tended to make 80% more conceptual decisions than teachers with lower ability students. Teachers’ explanations for that difference were based on their perceptions of students’ ability. Teachers with higher ability students perceived them to be more intelligent and able to handle numerous concepts and make sense out of those concepts. Teachers whose students scored below average performance on the high-stakes tests perceived that their students were of lower ability and therefore could not make sense out of multiple concepts and use them successfully in their lives.

High-stakes testing: One of the most restricting factors for making conceptual decisions is the fear of lower performance on the high-stakes tests. Classroom observations showed that the teachers understood that they are required to cover the concepts on the test. Therefore, the number of conceptual decisions made was inversely proportional to the amount of time teachers spent covering the required concepts. This also relates to ability, because the teachers of lower ability students assumed they would take longer to comprehend the given concepts, whereas higher ability students would spend less time.

Teacher's beliefs and thinking. Teachers' beliefs about science teaching and learning play some role in their conceptual decisions. Teachers who believe that students have to pass the high-stakes test may decide not to cover broad science concepts. Some teachers delay conceptual decisions because they think that introducing concepts from later chapters will confuse their students. In some instances, Daisy and Vera tried to keep earlier concepts separate from those they were teaching because they feared that students would get confused. On the other hand, Jane and Michael think that integrating science concepts is the key to better understanding science.

Research Question 3

Research Question 3 asked, What interactions occur between teachers and students when students share or bring their experiences to the classrooms?

Teachers in the study discussed being uncomfortable allowing students to lead science discussions, because student discourses can be very challenging to address. Students in some classes are very keen on sharing and leading the discussions, but the teacher must keep them on track. Jane is the only teacher who seemed very comfortable with students leading the discussion. Teachers who believe that learning happens in an environment with active interaction recognize the opportunities for students to share their experiences. Jane and Michael both encouraged students to participate and discuss their ideas, views, and thinking with others and lead the discussion in the group; however, they remained participants and kept the discussion on track. Teachers who decide to allow students to bring their views, questions, experiences and ideas into the classroom have a successful, student-centered, constructivist classroom environment (Brickhouse & Bodner, 1990; Clark, 2003; Resnick, 1989). These teachers view their curriculum as a constructivist curriculum, where students and teachers have equal stakes for success (Hillocks, 1998).

When teachers construct a micro-curriculum with student input during teaching, students feel more responsible for their learning. Students become an integral part of the teaching and learning process. Jane and Michael showed the desire and willingness to have students bring in their input during science learning. Jane described her decision about allowing students to be a part of her curricular design:

> My class is one that gives them learning environment and exposure to new things in life and makes them more aware of what they do. I treat them as equal stakeholders in building my classroom environment and what I have to teach…..In a discovering environment students are part of what I am teaching and they are learning….Students feel responsible for their learning if I allow them to lead the discussions. I do feel that from time to time I have to decide who speaks and who doesn't, because a little bit of structure helps to guide better learning.

Whatever the extent of a constructivist curriculum, teachers who use it in students' science learning find it to be worthwhile. This study also elucidates that constructivist curricula may help attain a better learning environment, higher confidence building among students, more critical thinking activities, and a higher level of awareness for responsible learning. This study reaffirms Corno (1989), McCarty et al. (1991), and Michaels's (1981) findings that teachers have to reconstruct classroom curriculums that use students' background knowledge to promote a higher level of critical thinking. The LiFE curriculum advocates this kind of curriculum. In the LiFE curriculum, teachers use students' experiences and their prior knowledge during discussions and hands-on activities. Students use science concepts learned in the LiFE curriculum to explain their experiences. Students more often think about shared experiences critically because they can discuss those experiences in an environment that supports their input.

Teachers who are in low-performing schools are under greater pressure to follow the district curriculum both at the macro-level and at the micro-level. In this case, the tendency among teachers is to complete the curriculum to satisfy the administration (Calderhead, 1996; Clark & Peterson, 1986). These teachers have a harder time creating a micro-curriculum during teaching that has a substantial amount of student input. These teachers are concerned that the science content may not be covered on time, and thus their students may not have the opportunity to complete activities, including hands-on learning. Therefore, students have few opportunities to lead discussions in science classes.

Teachers constantly struggle to apply the constructivist learning theory in a meaningful manner; they are torn between task completion and lengthy discussions whose outcomes are not certain. Teachers have very little time, resources, and administrative support for true discovery learning where students are the leaders in knowledge construction.

Social scaffolding in the science classroom comes with a premium both on time and on teachers' ability to direct the class energy towards science learning. Many teachers, including some in this study, believe that their goal as teachers is to focus on teaching content rather than on establishing rules for social interaction. In this study, teachers seemed to understand and realize that the more cooperative and caring the social environment, the greater the student input in science learning. Delpit (1988, 1995) and Ladson-Billings (1995) both argued that teachers have to change the classroom environment in ways that resemble students' home environment for greater participation in the classroom. This study found that teachers who allow a homey environment are successful in having higher participation in the class.

Jane and Michael utilized positive social interactions productively to promote critical thinking and a working relationship between the teachers and the students. Observations of Jane and Michael's classes showed that the caring nature of social interactions produces a relaxed classroom atmosphere. Many new concepts are introduced during science classes, and teachers become facilitators rather than knowledge banks with absolute power. The following remark from Jane sums up the effect of social interactions on students learning: “Learning science is a community-based activity where individuals have stakes, thus allowing them [students] to construct knowledge and seek more knowledge in an environment of mutual sharing.”

This study elucidates another key part of social scaffolding: Classrooms are social environments that have to allow constructive discussions to promote learning. This supports the view that cognition is a social engagement where individuals participate in discourse communities to generate knowledge and for understanding (Artiles, 1996; Fish, 1980; Lave & Wegner, 2003; Resnick, 1991).

Teachers’ Thinking and Decisions about Science Process Skills

All teachers in this study agreed that elementary school students have to master science process skills. To all teachers, science process skills included performing an experiment, measurement, observation, calculation, and writing conclusions. However, Jane included more than these five generic process skills. She emphasized that students must master the ability to generate questions, hypothesize, and apply the hypothesis to a real-life situation. The LiFE curriculum was very influential in Jane’s decision to incorporate skills that exceed the traditional idea of scientific process.

Teachers in the study emphasized that their decisions to make the students repeat the science processes verbally or orally guarantee that students will answer the statewide high-stakes test questions correctly. The high-stakes test curriculum demands that elementary level students master science process skills in order to “understand” and “perform science experiments” (Texas Administrative Code, 1998). The teachers also believe that their job is to teach students that all science experiments are based on similar science process skills. The teachers believe that it is imperative that the students be able to describe the how-to of an experiment. Teachers whose schools are designated as “low performing” may be more inclined to make decisions that are for immediate success (i.e., helping the school achieve “better performing” status) despite their desire to be more critical about science process skills. In this study, Jane was alone when it came to expanding the horizon of science process skills. In her class she used the QuEST cycle to introduce how scientists think about interesting questions and how they find the answers to those questions. She not only covered the science process skills, important for passing the statewide high-stakes test, but also introduced aspects of the nature of science. Teachers in the study reported fear that not teaching science process skills would show lower performance in high-stakes tests, because 25% of the state science curriculum is about teaching science process skills. Therefore, teachers in the study emphasized science process skills so that students could answer the statewide high-stakes test questions correctly.

This study demonstrated the constant struggle between teachers' decisions on what is good for learning science and what is good for the students to achieve. In this study, teachers' decisions to teach science process skills were mostly based on (a) passing high-stakes test, (b) getting the right answer in an experiment, and (c) performing an experiment without wasting time.

Implications

The implications of this study are numerous in the areas of urban science education, teacher education programs, curriculum development, curriculum implementation, and student learning. The way teachers in urban schools think about their science curriculum seems to be traditional in nature, despite the complex diversity present in the schools where they teach. Teachers recognize that teaching science in urban schools requires better understanding of urban society. The sociocultural structures in urban schools are diverse, and teachers need to adjust their science curriculum accordingly. The LiFE curriculum can be used as a benchmark to understand the nature, structure, and scope of a science curriculum that supports science education in urban schools. Because the LiFE curriculum is designed to help urban students learn science, it is structured to incorporate students' experiences and knowledge into the everyday classroom curriculum. Therefore, this curriculum is uniquely friendly to the urban science classroom.

This study also affirmed the findings from Hillocks's (1998) research: Teachers have uniquely differentiated epistemological understanding of curriculum. For some teachers, the curriculum is a list of contents and district mandates that need to be covered in a given time frame with little input from students. Other teachers engage in generating a constructivist curriculum that allows student input as a part of the everyday curriculum. A constructivist curriculum provides opportunity to diverse populations of students to share out-of-school knowledge and experiences in learning science.

Teachers' decisions about curriculum and curriculum implementation are based on their beliefs about science content necessary to further science learning. This study suggests that curriculum developers and implementers need to address the need to generate micro-levels of the curriculum to suit students' needs. Teachers' decisions are also based on the context that is created during social interactions in the classroom. Students and teachers relate to each other in a given context, generating a new context. Social interactions allow teachers and students to co-construct a new context in which science learning takes place. As the interactions take place in new context, new cues are generated with newly negotiated meanings, contributing in the process to building a learning environment that construes learning in a more mutual fashion.

Teacher education programs have to incorporate issues of context-specific learning, urban education, and constructivist curriculum design. This study provides evidence that teaching science in a meaningful manner requires specialized knowledge of the urban environment, urban curriculum, and students' experiences as a part of learning. Teacher education programs have to prepare teachers to recognize and practice this knowledge in ways that can help them during classroom teaching. Teacher education programs have to seek to understand teachers' thinking about teaching urban students, using their experiences in teaching, and creating social interactions that could help science learning.

Administrative influence is an important part of teachers' thinking and their decision-making process. However, decisions from teachers in low-performing schools are more influenced by administrative pressures and demands than those from teachers in high-performing schools. The study points out that high-stakes tests influence teachers' thinking and classroom decisions more so than the absence of those tests. Teachers in high-performing schools also make very specific decisions about the nature and the scope of the science content that they teach because their students have to pass the high-stakes test to keep the school in the high-performing category.

Future Research

More rigorous research on urban schools and teacher thinking has to be conducted to understand the discourse of both these fields. Also, such integrated research allows the inclusion of teacher thinking and student learning as a part of urban science education. Further investigation is needed to determine the extent that student experiences influence teachers' thinking and their decision-making process during classroom interaction. More study in this area can help science and mathematics educators design science curriculum that allows students to be a part of the everyday curriculum. A continued study of teacher thinking during curriculum implementation is also desired. In this study, the small sample of teachers provides some indication of how teachers think during curriculum implementation. A reform-based curriculum such as the LiFE curriculum is unique by design because it is designed to serve urban schools. Thus, a larger study potentially could generate better and more generalizable findings regarding teachers using curricula like the LiFE curriculum.

Summary

Teachers' thinking during classroom teaching connects what students bring into the classroom and what the teachers teach. Teachers make conceptual and managerial decisions in the class based on their prior experiences, student ability, and school performance and high-stakes tests. Also, teachers face a constant struggle between what they are obligated to do in the class and what they like to do based on their beliefs and understanding of the subject. Learning is an interactive communal process, and the classroom is a community where students have to interact and learn. Therefore, classrooms have to support interactive communal actions. Teachers are leaders who make this learning happen. All implications discussed above are important to provide an effective and constructive science learning environment.

APPENDIX A

SAMPLE CODE DEVELOPMENT BY NVIVO

SAMPLE CODE DEVELOPMENT BY NVIVO

NVivo revision 2.0.163

Project: Dissertation User: Bhaskar Upadhyay Date: 6/27/2004 -1:28:16 PM

NODE LISTING

Nodes in Set: All Nodes
Created: 3/20/2004 - 3:18:00 PM
Modified: 6/1/2004 - 1:21:56 PM
Number of Nodes: 22

1	Social Scaffolding
2	Students' understanding of teacher
3	Teachers' guidance to discussion
4	Teachers' understanding of student
5	(1) /Social Scaffolding
6	(1 1) /Social Scaffolding/Students' Perceived Understanding
7	(1 2) /Social Scaffolding/Teachers' thinking about student response
8	(1 3) /Social Scaffolding/Teachers' guidance in discussion
9	(2) /Analytical Scaffolding
10	(2 1) /Analytical Scaffolding/Being a scientist
11	(2 1 1) /Analytical Scaffolding/Being a scientist/QuEST Cycle
12	(2 2) /Analytical Scaffolding/Applying to life experiences
13	(2 3) /Analytical Scaffolding/Teachers' conceptual decisions
14	(2 4) /Analytical Scaffolding/Critical Thinking
15	(2 5) /Analytical Scaffolding/Classroom Decision
16	(3) /Personal Experiences in Science
17	(3 1) /Personal Experiences in Science/Teachers' Experience
18	(3 2) /Personal Experiences in Science/Students' Experiences
19	(4) /Planning for lesson
20	(4 1) /Planning for lesson/Thinking during planning
21	(5) /Passing the Test
22	(6) /Administrative Pressure

APPENDIX B

SAMPLE OF PARTICIPANT INTERVIEW TRANSCRIPT

SAMPLE INTERVIEW TRANSCRIPT OF JANE

Researcher: Couple of questions from the previous interview, elaborations and clarifications. You talked at two points during or interview that lots of elementary school teachers are not prepared well for teaching science. What do you think and how do you plan and teach your class so that you can provide the best science to your students despite having little science during teacher preparation classes?
Jane: It depends on what the subject is we are doing. We have resources like books and teachers' materials from where I get lots of necessary information. Textbooks, read the materials, I try to forget about what things they are already exposed. I think one time we all talked about seeds. We all know that seeds need dirt, water, air, sunshine, so I try to go pass that assuming that they know the basics. We start getting into photosynthesis, because parts of the plants. They know stems, roots, leaves, the inside of the seeds for example. So, I try to take them back to the basics that they need to know the things that they haven't already learned and have the foundations and then the materials that is to be covered for the grade level and I have some basic elementary books for different projects and I read them and high light the things that needs to brought out and the things they bring and tie it up all together. But lot of the assumptions that they know this and you get into the class and you realize that you though they were bringing didn't bring or brought with gross misconceptions or misunderstanding.

Researcher: How do you cope with the misconceptions or when they don't bring the things that you though they will bring into the classroom?
Jane: I try to think things that are real to them, for example, a potato, where did that potato come from because that is very different from other seeds like bean seed. They think seed like bean seed as opposed to cutting the eyes of the potatoes and planting them. So, something like that would be, having to bring something in and showing them or relating back to something that they already know or have experienced. So, their concept of seed is more of like bean seed or pea seed or corn but not the potatoes or onion bulbs or garlic. I process their information and try to relate to what I know and what they know and connect them to the context as well as the content. Try to find something that they know and their knowledge which is very limited in many ways partly because of their socio-economic area and partly because our kids don't cut on TV and watch the discovery channel, and partly because many of them come from undocumented immigrants and partly because they come mostly from minority, Hispanic families. There is no one encouraging them to watch informative programs at home. So lots of our kids bring very little to the classroom. So, it is difficult to find things that I can relate to their lives. If you're going try to turn something that they've already set in their mind is one way and is not other thing.

Researcher: So when you are planning or teaching for such situations, what do you do? How do you think through this situation so that you can help the children?
Jane: I really try to think at the top and go backward.

Researcher: Meaning..
Jane: Meaning I take where I wanna go with the like what is skeleton ? What is the focus of having skeleton, why do we have them, why do we have bones? What good are they? And then I break it down and plan for the each break down. But when I teach I start from the bottom and go back up. Think about you bones and I start where I want to be and then I back track and try to figure out what they are bringing with them and how much they know and what we can do like putting jump rope exercise where they can see different body parts in action. So, body is a machine and we will talk about how each part in that machine operates with lot of intricate co-ordinations. We then talk about the different types of bones. Are all the bones same? Why is wrist bone move different way than your straight-arm or finger, you know, how they are different? And why can you bend your wrist but only half way through with your arm. I try to take the top part, where we want to be, and then with other sub sections I help myself to reach there. I go backward to the main goal of the lesson and think about how I am going to get there and then I keep on going backwards and backwards finding out where I am really going to have to start. I start with pictures, with posters, things that they can feel such as taking the fingers together and having them move or feel or hold things and realize the importance of a thumb, joints and I try to keep the main goal (top) and then start from there and go down as I am planning at home. Sometime I realize that there is a too big of a gap and then I will never gonna reach there. Sometimes I plan for two days at a time and break the lesson into two days because the time period is too short that I know that this just one lesson but I have to put them in two days. So sometimes I look at things in a two-day time frame otherwise it will not work. So then I have to cut it back and realize that the top goal is far behind my desired point and then try to back up. Unfortunately there are times when I just have to move on even if they don't get it because of time, material, resources, support, guidelines, the tests that are coming through such as the nine-week test that is coming soon, CGI.

Researcher: So you already got the next 9-week lesson kit?
Jane: The FOSS kit, skeleton system, is they but this year they added more focus on the scientific processes so we are trying to get those from the book. One question in the nine-week test was to do with the dependent and independent variables and we never covered that so lot of it is the process and shows me where I neglected. Now I have break down the experiments further and tell them that

these are the variables and braking down to that vocabulary that the kids can recognize is important because even if we had done exactly the same experiment but if the vocabulary doesn't match. So, the kids will not be able to understand the question and answer them or comprehend properly. To me it seems that the vocabulary is crucial than understanding the process of experiment and I have to co-ordinate that more in this regard.
I think where do I start and where am I going to go by the end of the class. Sometime I go where am I supposed to be and that is what I am talking about the top. Ok we are going to have to go through the whole scoop, and then the parts. Now I kind of look at it where I ended up being.

Researcher: So, when you plan you, you go from the top to bottom but when you teach you go from bottom up.
Jane: Before I teach it I go back to the beginning to make sure that I have made the connection. If I don't with the next step because you can't go from skull to whole body. There are muscles and tendons and ligaments and veins and when I get to the bottom, I reverse it before I teach it and make sure that I didn't leave out a step and they didn't make what it makes kids to mixed up or confused. If I don't know where I am going, I get side tracked that's why I look at the big picture first and I look at the big picture and do go back and start and think about it. If I don't know where I am going I may get side tracked and start doing heart or brain and never get back where I supposed to be. So, sometime I do start from the beginning when I start planning but I always look to see where I supposed to end up. It depends on what it is that makes me go back wards or forward. I need to know where that goal is but that half unit or that unit or that section because I can find myself way out there.

Researcher: When you are teaching last time you said that lot of kids don't want to share what they think and are always afraid of saying something wrong. They look at the intelligent one for the answer. You want to make sure that science is a safe subject where students' can speak their minds and learn from their mistakes. When that happens in your class, would you describe for me what you are thinking when that happens in your class?
Jane: I keep thinking about that particular kind of students about how I am going to help them understand the appropriate concept using the student's answer or idea. I ponder about various paths that might fit to answer the question or problem so that the students learn from the errors. I have to take them from point A to point B and I just start grabbing. Most of the time it's not planned. Most of the time you're saying I can't plan it. Is the pendulum going to swing more time with the longer the string or shorter the string? They will say longer and you are like OK let's try and find out. So, lot of time you cannot convince them but they will say you're the teacher you're right. But I am not sure, … there was a girl last

year that I could never convince her when drawings came for the skeleton when the drawings came it looked like a frog and I bought books and pictures and how do you get a child who sees the frog legs like this (showing with her hand) and thinks about us jumping and that really a part of the frog family. You just keep trying. Sometimes it's just panic. It's not planned. It's grabbing whatever comes into your mind and some days you are sharper than other days. That you can't plan that our because you don't know what will happen. You just start asking questions and if you can show them better or try to make them think or you think what about when light and dark; when it's really dark do you see the nightlight or the streetlight, you know. You just have to go back what they have experienced themselves. You just grabbing that moment and experience and bring them back to their world that relate to other things where they can make sense out of whatever you are saying or doing or they are reading and doing.

Researcher: Can you give me an example where this happened (relating to their world)?
Jane: Specific one?

Researcher: Yes.
Jane: OK. It's 100 degrees outside it doesn't matter there is same temperature everywhere. Unless you take an actual bowl of ice and put one in a shady spot with the thermometer or without the thermometer at first under a shade or overhang and one under the blacktop and sit out there an almost watch with them to see which one melted more. The black to heated the blacktop made it hotter so you have to show them exactly what happened other wise she is the teacher and she said it so the answer is black top and it's gonna melt more. I know that if there is a 100 degrees out there, there is 100 degrees no matter where you are. So unless you can actually take them and show them a lot of our kids do not believe and do not think through the process. They have to be shown evidence or proof and if you don't watch it, they will think that somebody stirred it or some body took the ice cubes. They are very hard to convince. They will give you what they think you want to hear but the process is almost we got to do it and it is always constant thinking and the process in my head is that what can I do to show them that the temperature outside on the blacktop is hotter than under the shade. Even though temperature is 100 degrees outside but different places the heat is different. So, sometimes you do pull from your experience and little experiments and improvisations that you can come up with. Just letting them thinking, you had the bad experiment where the beans were growing better in the closet than out on the window. They grew better with no light than with light, they were growing and the ones on the window were not growing well at all. So that one was something that the kids had not experienced or seen before, but now what happened. The room was too cold that year than usual and you take those things

into consideration. We could have kids walking out of her thinking that it grows in the darkness and we did this in science. So, whatever they told us before is not true because we saw the beans grow in the closet without sunshine better than with the sunshine. So it's a fine line to walk that if you don't show or if they don't experience they can't think to think in those terms. All of that is we did very little in the kindergarten, first grade, second grade, third grade. They go through the motion that is the steps of doing experiment but nobody tells them why things happen the way they happen or what is happening and when they see the similar situation or situations. You can probably roll a marble down the ramp and a car down the ramp and they will see those two situations entirely two different situations because they never been, no-one has gone to them and talked about enquiring and the higher you move in critical thinking and establishing the process of scientific thinking and learning. The higher the car or the ball starts from the faster it moves at the bottom of the slope. The problem is that if they had done it or possibly done it in that thinking manner they would have been better equipped in understanding science and its nature. Since nobody has done it and taken the time to back up and tell the kids why (with stress) that happens and let's look at it and do the experiment differently. They do the one experiment and they're done and we move on and I'm trying to change that with very limited knowledge of science.

Researcher: No. You have lot of knowledge.
Jane: If just do the FOSS kit then, it's panic for me because I'm not sure that I covered the most important aspect of science that is critical thinking and asking questions. Because sometimes I'm not sure where I'm gonna go in terms of thinking and asking questions.

Researcher: The panic is because you haven't done it before in 9-week blocks or it was not mandated or just the management of the class.
Jane: What do you mean by not mandated?

Researcher: When you think about process, you wondered how you would pull it off in the class?
Jane: Because it is not what I thought I was going to be doing. If I came up with this nice neat lesson plan and the child goes no that isn't going to work; that doesn't work. And then you're going Ok before we can build on that we've got to change that child's point of view. Then it's panic. Ok what do I have in the closet, what can we (long pause) drop the die in the water and watch it and we can see the molecule action and where we go from there and lot times how fast can you think on your feet and I'm not a fast thinker and I go home and think why didn't I think of that thing or why didn't I do that thing.

Researcher: Would you mind telling me is that because you didn't plan it or is that because of nine-week curriculum schedule or administrative pressure?
Jane: Part of it is we don't know where our kids are and I don't care what it says was taught in third grade. You can teach it, they understood it, they retained and they're bringing them with them to the next grade level. I don't think it is beaurocratic fault. A lot of it, one my assumption that they know this; two how do get kids to think. It has always been that how do you get them not just do what you ask them to do but beyond the box or outside of the box and so lot of it is (a pause). I don't really think that the management can really be blamed on this, I think it's more how prepared I am when I come into the class- some days I'm better prepared than other days; how much I know the kids both academically, socially and culturally, what I believe about the kids abilities, what I expect them to bring to the class, what is their context at home. And there is that I am more comfortable teaching this pat of science than other parts because I understand this part of science. I do not and if you talk about television rays and all these rays, I've got to read and I've got to do my homework because I don't feel comfortable explaining to kids how it works. Lot of that is my part of work and preparation and understanding.

Researcher: When you talk about the QuEST Cycle and you said that there are many steps between generating a question or questions and getting the answer. Why do you think that this is really important for kids to understand and do in the class?
Jane: I think in life it is not like there is this question and there is this answer. And the answer to this might not be the same answer five years from now and our kids are programmed to give the right answer and so I was (short pause) What I want them to believe that what if you change your mind or the experiment or the process and getting a right answer once doesn't mean that it is forever. Situations, time, knowledge, instruments, change all the time and that science is their life and our life and it is constantly changing. Moving by without acknowledging the changes that have happened will only create a passive learning community of students. The more you do it when you're talking to kids and how important it is for them to realize that there are all; everything is not in a nicely ordered file and you just turn one file to another they are all mingled and like funnel cake, you know (laughs). All these things are connected and how all these things go together and you just don't pull this one file and say this is it and the answer to this is this and tomorrow the answer to this is this. That science is our world and our life and it is all intermixed and what we do whether we're doing such as reading, wring, walking to McDonald or whatever it is there is a bigger consequences when you go and put that wrapper in the recycling bin or in the trash. Using Styrofoam to paper cup or when you burn fuel or use a lot of electricity that all of these things are related. So, from the question to get to the

answer that there are all these side issues that may change the answer or that may not but there is other things going on as you get to the answer. It is just that I want them to be ware of that and that is where I think, I was going with that. My personal policy is to watch the kids so that they understand what science is about and how important is that for their lives. They will be the product of our nation and I know that when Sputnik, you know, they did that then there was a big push in science in the classes. Then science dropped off when we went to something else and that we didn't pursue it. We have scientifically illiterate teachers and kids. Except for the ones (kids) that are naturally driven to learn science or interested and retain it. You know, those three little kids who are exceptional and the others can read the same book but tomorrow they couldn't tell you anything out of that book.

APPENDIX C

SAMPLE LiFE LESSON

Learning is A QuEST

The key feature of the LiFE curriculum is that the above goals are accomplished through active learning methods.

Active learning needs to occur in two contexts at the same time: *students need to physically apply as well as mentally engage themselves* in the learning process. Active learning needs to involve students in a way that is both "hands-on" and "minds-on." The basis for the learning process in this curriculum is embodied in the Learning Cycle described below.

The LEARNING CYCLE uses active learning methods that include the following:

1. **Inquiry-based teaching** -- to develop among students openness of mind and curiosity along with skepticism and the need for evidence; the ability to ask questions, to make predictions or hypotheses and to think of ways to answer the questions; and the ability to make comparisons and draw well-thought out conclusions.
2. **Hands-on activities** -- to provide concrete materials with which to experiment and concrete experiences from which to learn.
3. **Collaborative work** -- to enhance among students' communication skills, interpersonal skills for teamwork and understanding of themselves as members of a community of scientists.

The QuEST LEARNING CYCLE and "The Scientific Method"

We have all learned about "the scientific method" many times, from elementary school on up. It is usually stated as including the following steps:

1. Making observations
2. Stating a hypothesis
3. Designing and conducting an experiment to test the hypothesis
4. Drawing conclusions from the experiment

You will see that these steps constitute the first two phases of the LEARNING CYCLE.

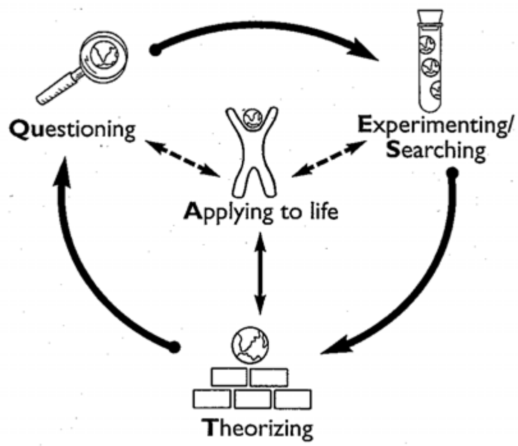
The National Standards and Benchmarks suggest that scientific investigations may take many different forms, including observing what things are like or observing changes over time and making inferences, as well as doing experiments.

The National Standards and Benchmarks also suggest that in addition to making observations, and designing and conducting investigations, scientific inquiry includes use of evidence to justify statements; use of logical reasoning and critical thinking to link evidence and explanations; and use of communication skills to describe observations, summarize results, articulate theories and constructs about how the world works, consider alternative explanations, challenge the explanations proposed by others as well as accept the skepticism of others; and apply scientific constructs and processes to everyday decisions and actions.

The QuEST LEARNING CYCLE thus has two additional phases: **Building theories/constructs** and **Applying to life**

These last two phases of the LEARNING CYCLE are especially important. While *exploring* and *experimenting* are often more fun for children and easier to do, the last two phases will help children refine their abilities to construct explanations and theories about what they have learned from their exploring and experimenting and to apply their leaning to their everyday lives. Your special attention and help are thus particularly needed in these two phases.

The QuEST LEARNING CYCLE involves the following sequential phases:



Questioning. Students explore their prior knowledge and experiences related to the area of study and develop and refine meaningful questions to guide further inquiry.

Experimenting/searching. Students plan experiments to answer the questions within the area of study. Thus, students identify problems, state hypotheses and select methods to test them, and interpret the results from these experiments to further their knowledge

Applying to life. Students apply the new constructs and processes they learned through the unit to decisions and actions they make each day. Students develop new questions to continue their exploration in the area of study.

Theorizing. Students continue to reflect on what they learned thus far to develop their own theories and constructs about how the world works. Students gain skills that enable them to articulate theories, give evidence to support their arguments and appropriately challenge others when working in small groups.

The LEARNING CYCLE is repeated many times throughout the curriculum. We believe that this repeated exposure and participation will make the LEARNING CYCLE approach to problem solving a part of your and your students' ways of knowing and acting.

Format of lessons

This Teacher's Guide contains all the plans you will need to teach the LiFE curriculum. Many lessons also include a description of extension activities that children can do at home or in the community. Each lesson includes:

- **Aim**

  A short one sentence description of what the students will accomplish in this lesson. Teachers can use this in their lesson planning and to write on the board for the students to understand the goal of the lesson.

- **Overview**

  A few sentence description of what occurs during the lesson

- **Science and nutrition concepts**

  A bulleted outline of the key concepts the students learn in this lesson.

- **Scientific processes**

  A bulleted outline of what scientific processes the students take part in during the lesson.

- **Objectives**

  A list of behavioral objectives the students meet as a result of this lesson. Bloom's taxonomy was used in the development of these objectives.

- **Materials and preparation**

  A list of all the materials needed for the lesson and any preparation the teachers will need to do before the lesson.

- **Key terms and definitions**

  The key terms introduced in the lesson, with definitions. Teachers can use these to review during the lesson, or as general vocabulary words for the week.

- **Background information for teachers**

  Information for the teachers to gain a deeper understanding of the content of the lesson, to feel more comfortable teaching it and to be able to use as guidance for questions the students ask.

- **Procedure**

  A step-by-step list with bulleted explanations of what to do for each part of the lesson.

- **Copies of student worksheets and Reading for LiFE**

  Copies of all worksheet and background readings the students use during the lesson.

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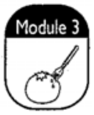
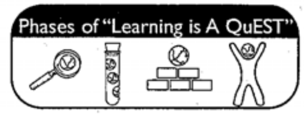




Unit 1 question: Why do we need food?

Lesson 1: Food has energy - it makes us GO

AIM

To analyze how food provides energy for our bodies.

OVERVIEW

This lesson begins with a discussion about energy to enable the students to understand that energy is defined as the ability to make things happen. We also want students to understand that energy comes in different forms, and that energy can change forms when it gets used. They will burn a marshmallow, cracker and peanut. First they will burn all three foods analyzing the size, color and intensity of the flames. Then they will burn the foods a second time with beakers of water containing thermometers over each food to measure how much each food is able to raise the temperature of the water. They will repeat this experiment if time permits. They will analyze their results to compare the amount of energy in these foods. Finally, they will learn that scientists burn food in a similar way to get the calorie count that we see on the labels of food packages.

SCIENCE AND NUTRITION CONCEPTS

- Energy is defined as the ability to do work (make things happen); energy comes in different forms - light energy from the sun, chemical energy in food and in gasoline that powers buses. Energy gets used to make things move and help living things grow.
- Plants convert light energy from the sun into sugar (chemical energy).
- Burning food proves it has energy because the fire is the chemical energy in the food being converted into heat and light energy.
- When food is burned, the chemical energy in the food is converted to heat and light.
- Energy in food comes in three main sources: carbohydrate, fat and protein.

SCIENTIFIC PROCESSES

- Using a food burning experiment to learn about how food provides energy.
- Applying what they learned in the burning food experiment to understand energy conversion.

OBJECTIVES *Students will be able to:*

- Justify the argument that food energy comes from the sun.
- Defend that burning food proves that it has energy.
- Contrast how much energy is in a marshmallow, cracker and peanut through analyzing their results of the experiment.

MATERIALS

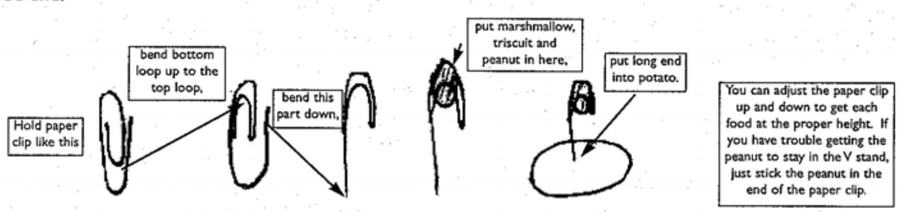
- 3 beaker stands or bricks (6 or 12) to hold up beakers
- 3 thermometers to go in beakers of water
- 3 250 ml beakers or 3 medium-sized cans (coffee cans or tuna cans work well if you are using bricks because of their wide base)
- 3 small potatoes (to use as food stands)
- 3 paper clips
- Matches
- Aluminum foil
- 6 large peanuts (if you have a student with severe peanut allergy use a hazelnut or macadamia nut)
- 6 mini marshmallows
- 2 Triscuits (divided into fourths)

KEY TERMS AND DEFINITIONS

- **burn** -- to supply fuel or energy to a fire
- **calorie** -- a unit of measurement for heat energy; the amount of heat needed to raise 1 gram of water 1 degree Celsius
- **carbohydrate** -- a compound in food which the body prefers to use as an immediate energy source but can also store for later use
- **chemical energy** -- the storage form of energy for plants and animals
- **energy** -- the ability to do work or produce a change
- **fat** -- a compound in food which the body can use as an immediate energy source but prefers to store for later use
- **protein** --a compound in food which the body uses to build structures and helps the body perform . Protein can also be broken down and used as energy
- **solar energy** -- energy given directly from sunshine in the form of heat
- **thermal energy** -- heat energy produced by living organisms

PREPARATION

Make paper clip stands to hold the marshmallow, cracker and peanut. Bend the paper clip as illustrated below. Stick the long end into the small potato. Place the foods (mini marshmallow, 1/4 triscuit. and peanut) in the V shaped end.



If you are using bricks, put them in a v, stacked 1 or 2 high, and place the can on top of the bricks. If you need a wider base, use a metal screen or aluminum foil (folded in quarters to add thickness) between the bricks and the cans.

If you are using beakers, beaker stands and thermometer holders, have this set-up complete before class.

Be sure that EACH food has the SAME DISTANCE between the food and the beaker or can. This is one of the controls in your experiment

BACKGROUND INFORMATION FOR THE TEACHER

In order to stay alive, our body needs energy to do work, to build and maintain its structure, and to perform a number of body processes. Many things, such as oxygen, exercise, water and sleep, help our body stay alive. This lesson focuses on the special role food plays in providing our body with energy.

Food has energy in the chemical form stored as carbohydrates, fat, protein and alcohol. In the body, various metabolic processes convert chemical energy in food to electrical, mechanical and thermal energy that the body uses to do work.

As we explored in the first module, plants transform the sun's energy into chemical energy by using water and carbon dioxide during photosynthesis. This process allows the plant to store food. In the body these stored foods are converted into the basic energy unit called glucose.

Different energy forms are used throughout the body. For example, the brain uses chemical energy and transforms it into electrical energy when brain and nerve activity takes place. The chemical energy in food is converted into mechanical energy in our muscles, while chemical energy is converted into thermal energy to regulate body temperature.

Energy in food and the body is measured in kilocalories (kcal), referred to as calories on food labels. Scientists can measure the energy in food by burning the food and measuring the increase in temperature resulting from the food being burnt. An approximation can be made by using a calculation method based on the average number of calories that each of the three energy-yielding macronutrients provides. That is:

1 gram (g) of carbohydrate	= 4 kcal
1 g of protein also	= 4 kcal
1 g fat	= 9 kcal
1 g alcohol	= 7 kcal.

Therefore, if a food has 20 grams of carbohydrate in it, it will have 80 Calories, (or kcal for short), from carbohydrates (20 grams x 4 Calories/gram= 80 Calories).

If a food has 5 grams of fat, then it will have 45 Calories from fat.

Most foods are a combination of carbohydrate, fat and protein. A food that 6 grams of carbohydrate, 4 grams of protein and 3 grams of fat will have 67 Calories -- (6 gram carbohydrate X4Calories/gram) +(4 grams proteinX4 Calories/gram) + (3 grams fat X9 Calories/gram).

NOTE: If you do these calculations with the grams of carbohydrate, protein and fat listed on a food label you may not get the same answer as the Calories listed on the label due to rounding.

When we eat, the body can do two things with the energy in the food: 1) use it immediately or 2) save it for later. When we eat more energy than our body needs we store it for later, generally as fat.

PROCEDURE

Questioning

1. Remind the students that the module question is, "How does food provide our body with what it needs?" The question for the first unit is, "Why do we need food?"

2. Explain that in this lesson they will learn about food providing us with energy.

   - Remind the students that all the energy in food comes from plants who capture and store light energy from the sun during the process of photosynthesis. Even though they may know this and be able to say it, in this lesson they are going to do an experiment to PROVE that food has energy.

3. Have a discussion about energy.

   The purpose of this discussion is to help the students think through three questions about energy:

   * What is the definition of energy?
   * What are the different forms of energy?
   * How does energy get used?

   - Here is a sample of how this conversation might go in your class. This is the level of discussion we would like. Your class may need more or less questioning to get to this level.

   Teacher: In this lesson we are going to learn how food provides us with energy. We all use the word energy a lot in daily conversation. What are some ways we talk about energy?

   Student: My mom always tell me to turn off the lights when I leave a room so I don't waste energy.

   Teacher: Good, that is referring to energy, usually in the form of electricity, that powers things in our homes.

   Student: When I play basketball for a long time I tell my friends I need a rest because I am out of energy.

   Teacher: Yes, our bodies use energy to make us move.

   Student: My dad runs in races and he eats lots of pasta the night before the race to give him energy to run.

PROCEDURE (CONTINUED)

Teacher: Yes, we get the energy to move our body from our food, which is what we are learning about today

Student: In third grade we learned about windmills and that they make energy.

Teacher: Yes, the movement of the wind is energy. Windmills can capture and store the energy in the wind so we can use it later. Now, ***does anyone know the definition of energy?***

Student: I don't know how to explain it, but energy seems to be involved in doing something, such as making a light go on, or making our body move.

Teacher: That is very close. The definition of energy is the ability to do work or to make things happen. So, the "something" you referred to is any type of work. Work can be powering a light bulb, heating up water so you have a hot shower, making your body move, or making a car move. One reason energy is so confusing is that there are many types, or forms of energy. From what we discussed so far ***can anyone tell me a form of energy?***

Student: I think light is one form of energy because we said earlier that plants use sunlight to make their energy.

Teacher: Yes, and light bulbs are another example where we see ***light energy****. Any other forms of energy?*

Student: Is gasoline a type of energy because it is used to make cars and buses move?

Teacher: Gasoline does represent another form of energy. It is called ***chemical energy*** *because the energy is inside the chemicals in the gasoline. Any other forms of energy?*

Student: Is food a type of energy because we get our energy from food?

Teacher: Good, food is actually another example of chemical energy because the energy in food is inside the chemicals in the food.

Student: I thought that chemicals were bad, there are chemicals in our food?

Teacher: I am glad you said that because probably other people were thinking the same thing. A chemical is really any substance made of different basic elements. Water is a chemical made of hydrogen and oxygen -- the chemical formula for water is H_2O. Some of the chemicals in our food that have energy are sugar and starches called carbohydrates,

As you have this discussion write some notes on the board for the students to record in their LiFE Logs. For the forms of energy, you may use the examples we have here, or the examples that come out of your class's conversation.

Definition of energy:

the ability to do work or to make things happen

Forms of energy:

light energy (examples -- sun and light bulbs)

chemical energy (examples -- gasoline and sugar)

heat energy (examples -- heater that keep our house warm, feeling hot when you are running)

mechanical energy (energy of motion) (examples -- a ball flying through the air, a car moving)

How energy gets used:

energy gets used by changing it from one form to another, such as light energy being turned into chemical energy during photosynthesis or chemical energy getting turned into mechanical energy to make a car go)

PROCEDURE (CONTINUED)

proteins and fats. Now we have two forms of energy, light energy that we see from the sun and light bulbs, and chemical energy that we now know is the type of energy in food and in gasoline. Any other forms of energy?

*Student: I think **heat might be a type of energy**. I know the sun gives us heat and my mom always says her energy bills are high in the winter because of heating our home.*

Teacher: Right, heat is another form of energy? Any other forms of energy?

Student: I know that things that are moving have energy, such as when we throw a ball. Is there a name for that type of energy?

*Teacher: Yes, **mechanical energy** is the form of energy in things that are moving. We have come up with four forms of energy, light, chemical, heat and mechanical. Does anyone have any questions?*

Student: If mechanical energy is the type of energy that makes things move, when we move our body is that an example of mechanical energy because we are moving or chemical energy because our food has chemical energy?

*Teacher: Now, that brings us to our third question, **how does energy get used?** This is a hard question, to get us started, can someone describe, in terms of energy, what happens during photosynthesis?*

Student: The plants use the light energy from the sun to make sugar which has energy in it.

Teacher: Right, and what type of energy is in sugar.

Student: Chemical energy.

Teacher: Excellent, so during photosynthesis light energy get changed or converted into chemical energy. What do you think happens in our body when we run?

Student: I think I got it! The chemical energy in the food gets turned into mechanical energy to make us move.

Teacher: Right, so how energy gets used is that it is changed from one form to another form. Next we are going to burn food, what energy change will go on when we do that?

Student: The chemical energy in the food will be changed into heat and light energy in the fire.

PROCEDURE (CONTINUED)

Teacher: To sum up our answer to how energy gets used, it gets used by changing one form of energy into another form. One final example of this is gasoline makes buses move because the chemical energy in the gasoline is changed into mechanical energy by the engine. Let's start our burning experiment.

Experimenting/Searching

4. Burn all of the foods and carefully observe the flame produced by each food.

- Put the marshmallow, cracker and peanut on the stands. Explain that there is about 1 gram of each food. We are starting with equal weights of each food.
- Assign a pair of students to each food to time how long each takes to burn. Explain to all the students that the length of time it takes each food to burn is not the only variable. As the foods burn they can watch the fire produced by each food to compare and contrast the ***size, shape, color*** of the fires.
- Light the peanut first (will take probably 2-3 matches to light and will burn for about 3 minutes). Light the Triscuit second (will light quickly and burn for about 90 seconds). Light the marshmallow last (will light quickly and only burn for about 30 seconds).

5. Discuss the results of this trial of the experiment.

- Make a simple table on the board to compare your results:

Food	Time	Size of fire	Shape of fire	Color of fire

- From these results what are the students guesses about which food has the most energy, which is in the middle and which has the least energy.
- During this discussion, review with the students that as the food burns the chemical energy in the food is being converted into light and heat energy in the fire. Help them understand that if we could measure the light or heat released in the fire we could measure the amount of energy in the food.

If you have a student with a **severe peanut allergy** that may be affected by burning a peanut in the classroom burn a hazelnut or macadamia nut.

If you can have three adults in the room. You can light all three foods at the same time.

PROCEDURE (CONTINUED)

6. Explain the retest that will add measuring how much each food is able to raise the temperature of water placed above the food.

   - Measuring how much the fire from each food is able to raise the temperature of the water measures how much energy is in each food.

   - Ask the students what they would want to do when setting up the test to make it a fair comparison between the foods. Help the students generate the following list:
     * Same weight of each food (each food weighs about 1 gram)
     * Same distance between the food and the water (about 1/2 inch between the food and the beaker will work fine)
     * Same amount of water in each beaker (put just enough water to cover the tip of the thermometer -- 50 mls of water in a 250 ml beaker works well. Less water will create more of a temperature change since there will be less water to heat)
     * Same (or very close) starting temperature for each beaker of water

   - These will assure that any differences in the results are from differences between the energy in each food.

Make sure the tip of the thermometer is in the water and not touching the beaker or metal can as the glass or metal will retain more heat than the water.

Be sure the students understand that the Temperature change is: Ending Temp - Starting temp

7. Conduct the energy burning test.

   - Set up a data table on the board similar to the SAMPLE data table below. All students can copy the data table into their LiFE Logs:

Food	Time	Starting Temp.	Ending Temp.	Temp. Change
Marshmallow	30 sec.	25°C	27°C	+2°C
Triscuit	1 min. 30 sec.	26°C	41°C	+15°C
Peanut	3 min 18 sec.	25°C	58°C	+33°C

   - Light the foods in the same order as you did for the first test. Once again assign pairs of students to time how long each food takes to burn.

   - If time permits, repeat the burning so that the students have two sets of data to compare.

PROCEDURE

Theorizing

8. Discuss the results of the experiment with the students, using the following questions and answers as a guide.

- How does burning food prove it has energy?
  * because the light and heat we see and feel from the fire is the energy in the food.
  * As the fire burns the CHEMICAL energy in the food is transformed into LIGHT and HEAT energy.
  * In our body we do not have a fire to burn food, rather chemical reactions transform the CHEMICAL energy in foods into MECHANICAL energy to enable us to move and HEAT energy to maintain our body temperature. The more energy our body uses the more heat we create, which is why physical activity that uses lots of MOVEMENT (mechanical energy) makes us get HOT (heat energy).
- Out of the three foods we burned, which has the least energy, which is in the middle and which has the most energy? How do you know?
  * The marshmallow has the least energy because it burned for the shortest time (although the flame was big) and raised the temperature of the water the least.
  * The Triscuit has the middle amount of energy because it burned for the middle amount of time and raised the temperature of the water the middle amount.
  * The peanut has the most energy. It burned the longest and raised the temperature of the water the most.
- How do scientists figure out how much energy is in food to put calorie counts on food packages?
  * When scientists are trying to determine exactly how much energy is in a food, the burning of the food takes place in a special burning device called a calorimeter. The calorimeter does not let any heat escape, all the heat produced from burning the food goes into the water to raise the temperature. By knowing how much water you have and how many degrees the water went up in temperature scientists can calculate precisely how much energy is in the food.

PROCEDURE (CONTINUED)

- Where does the energy in food come from?
  * All the energy in food comes from the sun: plants capture the sun's energy (light) and convert it into chemical energy that is stored in the plant (photosynthesis). We eat these plants as well as animals that eat plants, thereby obtaining the energy for our own use .

Applying to life

8. LiFE Log: If you were going on an all day hiking trip and could only bring one food, which of the three foods in today's experiment would bring to give you energy to last all day? Why? How do you know this?

- Ask a few students to read their entries out loud to see if they truly understand how burning food proves it has energy.

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